

**The application of cooperative learning to  
enhance the teaching of Nature of Science for  
scientific literacy advancement in secondary  
school physical science students**

by

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# Declaration

I, Nomonde Spellman, declare that the thesis, **The application of cooperative learning to enhance the teaching of nature of science for scientific literacy advancement in secondary school physical science students** is my own original work and has not been submitted to any other university for a degree. All sources have been fully acknowledged in the text and a list of references has been provided.

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**Nomonde Spellman**

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**Date**



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# Dedication

This work is dedicated to my husband, who survived a terrifying car accident and four months' hospitalization, yet still encouraged me to complete this project.

*This dedication is extended to the following:*

My children, who I had to leave at home when I attended my classes. My father, siblings and extended family members who had to attend family gatherings without me but still encouraged me to finish my studies and supported me even when it was they who needed me most. To them I say, 'May I be the inspiration you need and may God, your pillar of strength, keep you safe and well until you are able to realise your own dreams.'



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## Abstract

*The purpose of this study was to explore, demonstrate and apply cooperative learning when explicitly exposing Nature of Science (NoS) to physical science secondary students aiming at advancing scientific literacy. Secondary school physical science teachers with less than five years' physical science teaching experience participated in the workshop which demonstrated the understanding of NoS and how it can be used to uncover the students' likely misconceptions through classroom interactions and Pedagogic Content Knowledge (PCK). It was found that the knowledge of both components of PCK depended on one another and was interlinked with the understanding of NoS. The findings showed that the majority of the teachers who attended the workshop did not explicitly teach NoS and had problems with how it can be taught. Teachers rely on the telling method and hope to achieve concept mastery and scientific literacy. Driel et al. (1998) argued that good understanding of content knowledge is a prerequisite to the development of PCK. Teachers do not possess adequate PCK as they gave incorrect scientific answers. Though students enjoyed working in cooperative groups to advance scientific literacy, their teachers were less likely to uncover pupils' likely misconceptions. This was shown by the way they explained variations to student's scientific perceptions. Acknowledging the limitations posed by the number of participant and continuity of the administered treatment, the collected data were used to deduce that: teaching NoS explicitly and skillful application of cooperative learning can lead to improved scientific literacy and the need for skills to design classroom instructions with intent to explicitly expose NoS to the senior secondary students.*

# CHAPTER 1

## RATIONALE FOR THE STUDY

### 1.1 Introduction

This chapter provides the rationale for the study. The research was done in South Africa, and participants were from the rural schools of the Eastern Cape. The purpose of the study was to engage with physical science teachers in working together for the purpose of interacting and intervening in the crisis currently facing the education system. Working together and sharing good practices could yield teaching and learning improvements. The curriculum reform introduced in 2006 is known to demand knowledge and skills in order to be meaningful to a democratic South African society. The selection of subjects to be taught in schools is done (but not limited to) with an aim to redress the imbalances of the past and in consideration of the benefits such subjects would offer to the society and the economy of the country. According to the Trends in International Mathematics and Science Study (TIMSS) recorded in 2011, mathematics and science are key areas of knowledge for the development of individuals and the society.

South African mathematics and science achievements are still low though there have been traces of improvement from TIMSS (2002) to TIMSS (2011). The greatest improvement has been shown among students who can be described as the 'most disadvantaged' and who scored the lowest initially. This improvement, according to their research, was effected from the value of the continued endeavours and investments in less-resourced schools with the intention to improve school climate, resources and quality of teaching. Without students and teachers efforts, the support from households and the Department of Education would have been in vain. Extending the endeavours to continuous improvement, this research intended to expand on the wing of quality of teaching, hence the treatment in the application of cooperative learning (CL) in teaching nature of science (NoS) in secondary schools.

In conjunction with the aforementioned endeavours by different stakeholders, this study was undertaken to support teachers in exploring the benefits of teaching (NoS) explicitly in physical science senior secondary school students. The research would also strengthen the teachers' potential and abilities when teaching NoS using

cooperative learning. The endeavour was envisaged to be a means of strengthening student scientific literacy, arousing their curiosity and broadening their scientific reasoning, which, in turn, would be directed into achieving the aims of the South African curriculum. The knowledge of NoS might not change the classroom behaviour as it was alluded to by Lederman & Zeidler (1986); however, the understanding of NoS could facilitate the learning of science subject matter as supported by Lederman (2006) and enhance students' scientific literacy. With the application of relevant instructional strategies, the researcher strongly believes that improved and sustained student performance in physical science can be achieved even in the most rural and under resourced South African schools.

The researcher hoped to realise teachers' understanding of (CL) and the extent to which they use it in their everyday lesson presentations. The teachers (participants) and the researcher collaborated on the practical teaching of physical science and how best CL could be used to enhance the understanding of NoS in secondary school students for scientific literacy advancement. This then was done by means of the use of a questionnaire, teacher mentoring and co-teaching. The mentee would implement the lessons of the workshop programme in his or her physical science group of students. Data gathered using different research methods and instruments was analysed using the defined data analysis techniques discussed in chapter 6 of this study. This chapter presents the background and context to the study and describes the research problem leading to the research question. The significance and the limitation of the study are also highlighted.

## **1.2 Background**

TIMSS (2011) depicted a difference in professional satisfaction when benchmarking South African teachers. Their report showed a slightly lower professional satisfaction for South African teachers than international averages. 62% of South African science students are taught by teachers who are dissatisfied with their profession against international margins of 53% taught by teachers satisfied with their profession. The question here, therefore is, why teachers feel that way. Amongst many reasons, the shortages of science resources, student high failure rate and the noise made by the education department regarding poor student performance were the causes for job dissatisfaction.

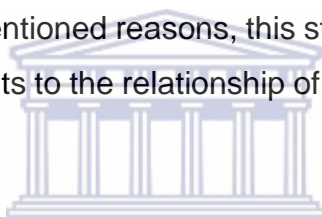
During the time of this research, one school in the Eastern Cape had produced a zero pass percentage in matriculation results. This was viewed as a let down by many people including the president of the country, even before any form of investigation was done as to why this was the case. Teachers still feel pressured to produce quality results in bigger quantities with limited or no resources to deliver such in some or most rural schools, particularly in the Eastern Cape. Teachers even resort to criminal acts where they assist students during exams in order to hide from the shame of poor performance as it was the case in one school during 2017 physical science national examinations. When the Department of Education (DoE) presented the Curriculum and Assessment Policy Statement (CAPS) in 2011 its emphasis was on encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truth. This according to Du Plessis (2013) lacks meaning as he claimed that it has little room for interpretation of what and how to teach. When this curriculum was unpacked, it was in the form of workshops with no further assessment done on teacher readiness before the time for implementation. Even today, there are still a number of teachers who do not know what is it that they are expected to do in order to achieve the general aims of the South African Curriculum as stipulated in the CAPS document.



In July 2014, the Minister of Education (MEC) in the Eastern Cape Province addressed the cabinet on the 2014/2015 budget and policy speech. He alluded to the successes the department had had in the previous years with regard to student performance and achievements in science projects. He regrettably failed to bring to the attention of the cabinet members that it was not only his and executive council members' efforts but the teachers' struggle as well. He made mention of challenges they were facing which, among many were; the operational strategy of the Mathematics, Science and Technology Academy that was not fully functional, the schools that were not aligned with the rest of the schooling system in the country and poor performance in the Annual National Assessment (ANA) which remained at very low levels. ANA is a programme administered at the General Education and Training (GET) band where students are assessed in English Language and Mathematics. In this assessment, science is not included. The belief is that when students have the understanding of mathematical and language skills, they would in turn enable the student to apply the attained skills to other subjects. According to my assessment, this can be true to a limited extent since I advocate for NoS – a way of thinking that

can assist the students understand scientifically concepts and become scientific literate. In the cabinet meeting, the expenditure framework of the year agreed upon encompassing many aspects including teacher demand and supply, full teacher utilization and teacher development.

Moving with the teacher development premise, the researcher's intentions were encouraged, which was developing teachers in teaching strategies within a particular framework, NoS. When one instructional teaching strategy does not seem to yield production expectations, on site practitioners are compelled to explore various strategies in order to remedy the situation. The same is true for physical science teachers; it becomes their duty to work out the possible instructional methods which could assist students so that they can reconceptualise science, not only for the purposes of attaining the highest performance levels, but also for them to grow as critical thinkers who are able to use scientific knowledge in broader contexts. In consideration of the aforementioned reasons, this study was done to enable teachers to trigger and expose students to the relationship of their scientific understanding and that of science rationale.



In the light of the researcher being a physical science teacher in one of the schools in the Eastern Cape, it became proper to engage in the struggle to find ways of working together, as practitioners, in order to find a way to work in line with these departmental resolutions. The researcher engaged physical science teachers in a mentoring programme to support them in the teaching of NoS using cooperative learning in order to advance scientific literacy. This was, in return, hoped to improve student performance. Four variables were taken into consideration during this research: teacher mentoring on how to incorporate cooperative learning when teaching nature of science to physical science secondary school students, how NoS knowledge can enhance scientific literacy in secondary school students, the effect of mentoring on teacher content knowledge and pedagogical knowledge, and how scientific literacy can benefit secondary school physical science students. These variables were then directly and indirectly linked to different studies done in the education fraternity by various researchers from different bodies of knowledge.

The reason why these domains were chosen was that there has been enormous work done on how they influence student performance in many countries, but there is very

little evidence of them being implemented in the South African context, particularly after the introduction of Curriculum Assessment Statement Policy (CAPS). South African research studies have focussed mainly on how student performance can be improved using strategies like incorporating science practical activities, science expo's and delivering computer based lessons. The researcher then felt the need of exploring other instructional methods in order to enrich the ones in existence, with the aim to intensify teacher efforts in improving secondary school physical science learning and student development, not only for classroom purposes but also for global science related interactions.

This research was informed by the fruitful results that are shown by different studies on how cooperative learning enhances teaching in different disciplines but on a more deliberate interaction (Jonson & Johnson, 2009). According to Ghoush, Qadir, Al-Lami, Al-Abdullah and Dash, (2016) productive engagement in peer interactions, collaborative reasoning and co-construction of knowledge leads to cognitive gains and are therefore effective tools for promoting higher learning level. In addition to this notion, physical science students can benefit from these higher levels of learning and advance scientific literacy. In this case, scientific literacy is one's understanding of the concepts, principles, theories, and processes of science as suggested by Abd-El-Khalick, Bell and Lederman (1997). The understanding of NoS provides students with an understanding of science as a discipline, and it provides a meaningful context for the subject matter that students are expected to learn. This research took its guidance from the research that is shown by different literature, particularly Lederman (2006), as he argued that NoS is advocated because of its inherent educational value in understanding science as a discipline, as opposed to it being anything of concrete instrumental value. However, an instructional strategy without the content knowledge would threaten the envisaged outcomes of the project – developing teachers in the use of different and tested teaching strategies that could positively contribute to the performance of physical science students.

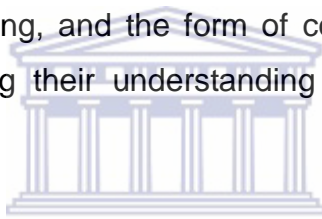
Positive contribution in this study means establishing scientific literacy in secondary school students and attaining improved and sustained student performance in physical science. The researcher then incorporated the pedagogical content knowledge as advised by Shulman (1986). In this research the understanding of NoS by the teachers and students was the focal framework with an aim to minimize

misconceptions. In order to minimize controversy and limitations in this study, one of the topics taught in the secondary school level was examined during the mentoring programme and also taught to students in class at the co-teaching stage of the research.

According to Lederman (1992), despite numerous attempts, including the major curricular reform efforts of the 1960s, to improve students' views of the scientific endeavour, students have consistently demonstrated inadequate understanding of several scientific aspects. He claimed its causality to the limited epistemology of nature of science (NoS) and scientific inquiry (SI). When referring to nature of science, Lederman talks of the epistemology of science, as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge. In the midst of teaching, the teacher has an obligation to intensify the use of science as the way of explaining and understanding scientific concepts, elevating and exposing the students' ability to use science, in class or outside class, whilst developing their science knowledge. In this regard, teachers need to be equipped to fulfil these obligations with relevant skills so as to advance the learning processes and to mitigate challenges that could hinder theirs and the system's intentions.

The understanding of such entity is not enough without the relevant skills and preparedness. According to Shulman (1986), teacher evaluation cannot be examined using some classroom facets like teacher planning or interactive decision making and leaving out others, such as what he understands to be content knowledge, which he further divides into subject matter content knowledge, pedagogical content knowledge and curricular knowledge. This research, therefore, was structured so that the three facets of the content knowledge were addressed during teacher development. This was of great consideration as one would struggle or even be unable to work with teachers without knowing their knowledge framework and how the subject matter was translated from the knowledge of the teacher to the content of instruction. Most of the explorations in this research have been focused on pedagogical content knowledge (PCK), which considers how science teachers utilise and translate content into a learning experience for students whilst aiming at establishing scientific conceptual understanding and mastery.

In the mentorship setting, the researcher worked closely with the novice physical science teachers, encouraging nature of science teaching and how it can assist in their everyday lessons with convincing teaching for prolonged understanding of science by students. In this way, their instructional teaching method would endorse learning and hoped to yield improved student performance. The programme also examined the importance of understanding the manner in which students learn, and causes for their poor conceptualisation of scientific context. Whilst teachers teach, they also have to explore what students already know, which could only be possible when information sharing is encouraged in class. Information sharing, therefore, should not only be vertical but also horizontal, hence cooperative learning and how teachers can integrate it in their everyday teaching was of significance. Therefore, the crucial exit point where the expert teacher would produce the expert students would be accomplished. The mentorship design took two forms, the workshop form during teacher induction on nature of science and how teachers can use this concept to facilitate and validate learning, and the form of co-teaching during the time when teachers were implementing their understanding of cooperative learning in their practical teaching.



Teacher-student interactions were also taken into consideration as the student understanding of scientific knowledge was prioritised. It therefore became imperative for teachers to understand what cooperative learning is and how to use it in a science class in order to achieve the desired outcomes, the development of student NoS, and these aspects combined were anticipated to yield a positive result, which was to enhance scientific literacy.

According to Fensham (2008), the confusion as to a precise meaning of scientific literacy has led to a call to remove such a term as a goal for school science education. However, Holbrook and Rannikmae (2007) suggested that retaining the use of scientific literacy was still appropriate, but it was necessary to relate scientific literacy to an appreciation of nature of science, personal learning attributes, including attitudes, and also to the development of social values.

While agreement on the meaning of scientific literacy, beyond the metaphorical use, is more or less universal, it has been identified that there are two major debates, or points of view. One group views and advocates scientific literacy as a central role for



the knowledge of science as they claim that there are fundamental ideas in science that are essential. Science content and knowledge is a crucial component of scientific literacy.

In this study, the researcher fused the two ideas, advocating that with the reasoning skills in a social context based on observation, experimentation, communication and rational deduction, the science knowledge could be systematic, verifiable, progressive, and useful. Furthermore, this approach would yield knowledge of science and essential fundamental ideas that might, if properly applied, attain the crucial components of scientific literacy. In order for the study to reveal these claims, the researcher used cooperative learning (CL) when teaching science to a participating group of students.

A number of studies have shown that the use of cooperative learning when teaching encourages learning and leads to improved student performance (Herreid, Gillies, & Ashman, 2005) and (Li & Lam, 2013). In agreement with other researchers, Johnson and Johnson (2009) argued that the success of cooperative learning is largely based on having a clear theoretical foundation as the preferred way for active learning procedures for teachers, and other research studies validate this argument. In order for cooperative learning practices to be effective in a classroom, teachers need to be equipped with skills in the actual implementation and need to provide regular mentoring and support, as cooperative learning teaching strategy is generally labelled as a time waster by practitioners. The research results as pointed out by Nwosu (2013) supports the effectiveness of cooperative learning as a teaching strategy. The results do not suggest that traditional teaching method is ineffective, rather, it argues that cooperative learning should be integrated with other teaching strategies. For this very reason, part of this research mentored teachers in how to skilfully use cooperative learning when teaching nature of science in a physical science classroom.

Teachers claim that students' outside classroom knowledge is somehow irrelevant. Allowing them to spend time in their groups makes it difficult for the teacher to correct a group that could have been misled by one student with alternate science conceptions, so they prefer students to keep their knowledge with them so that if it is not acceptable, then it is corrected without passing it on to other students. This

research was done taking into account the attitudes of teachers, as they prefer finishing the syllabus, due to the imposed pressure by the employer on the improved students' performance and it was, therefore, that very reason this research took this trajectory, to mentor teachers on the approach that has been tried and tested, to improve student performance.

In the early 1930's and 40's John Dewey, Kurt Lewin and Morton Deutsch influenced the cooperative learning theory practised today, which is seen to be more preferred by the DoE in the current curriculum delivery as stated in the general aims of the South African curriculum. The theory portrayed students as active recipients of knowledge by engaging one another in informative discussions rather than being passive information and knowledge receivers, of which, at times, that information makes no meaning to them. If what is taught does not correlate with the framework of the student, it is evident that the student will not be able to make connections and thereby no learning will take place due to the disconnections in the cognitive process.

Expertise in cognitive processes, as mediated by Chi, Glaser, & Rees (1982), is attained when individuals identify problems and operators, solution steps to solve such problems, and how these operators are ordered into a sequence of actions so as to reach an acceptable desired solution. In the case where students fail to make such connections, they will tend to develop their own concepts that are scientifically unacceptable. This then has to be avoided by challenging the understanding of the student's knowledge through robust discussions with peers in order to avoid the recurring misconceptions as there already exist in various domains of science due to its conjectural nature as a subject.

Over the past decade, amongst many other strategies, cooperative learning has become one of the most popular, but often misunderstood, instructional strategies that could be used to allow students to articulate their scientific knowledge. In this case, teachers' skills in the use of the controversial cooperative teaching and learning strategy were assessed and strengthened through mentoring in order to capacitate them in how to implement the strategy when teaching physical science. The programme addressed issues in preparing lessons that incorporate the use of cooperative teaching and learning and how best teachers can reconceptualise students' perceptions as learning progressed through scientific knowledge exchange

and discussions. With the conceptual change theory, as suggested by Posner, Strike, Hewson & Gertzog (1982), focusing on the notion of accommodation and the four suggested conditions which should be met for this type of change to occur, teachers were mentored in how to assist students to re-conceptualise.

From the extensive work done by Roger Johnson and David Johnson in the field of cooperative learning, suggest five defining elements of cooperative learning:

- *Positive interdependence* - a sense of sink or swim together. The success of an individual to a certain extent is dependent on the other.
- *Face-to-face promotive interaction* - helping one another learn, applauding effort and success. Helping one another yields promotive interaction whereby students exchange resources, testing hypothesis together and challenging each other's conclusions but at the end, based on scientific epistemology, arrive at the solution.
- *Individual and group accountability* - each of us has to contribute to the group achieving its goals. Each member of the group, to a certain extent, contributes to the assigned work so that when assessment is done, every individual is able to demonstrate effort and learning in the interaction process.
- *Interpersonal and small group skills* - communication, trust, leadership, decision making, and conflict resolution. Each group member has an obligation to know everyone in the group, appreciate their individual differences, embrace one another's strengths and above all develop their weaknesses into strengths. This enhances the communication and limits conflict.
- *Group processing* - reflecting on how well the team is functioning and how it can function even better. Feedback becomes vital for reflection for further improvement and facilitation of cooperative learning skills.

In my view, these elements could be erroneous without the significance of the interactions of these groups with the teacher in class. Moreover, the intervention of the teacher in the cases where there are misconceptions would not have a link with cooperative learning. To avoid teacher centeredness, teachers are to see themselves as mediators, hence scaffolding plays an integral role.

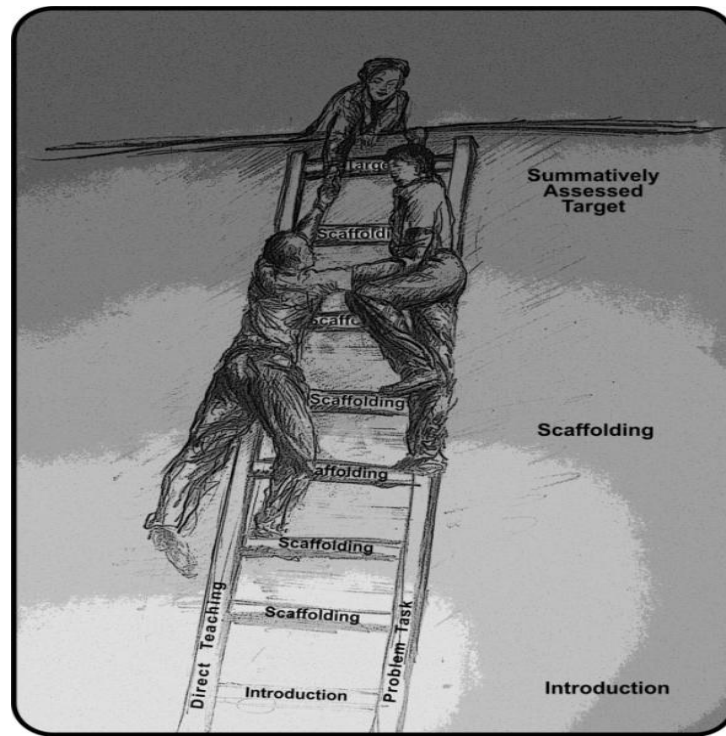


Figure 1: scaffolding tools which tie direct teaching and problem engagement together.

According to Vygotsky as cited by Cole, John-Steiner, Scribner & Souberman (1978) students' problem solving skills fall into three categories: skills which the student cannot perform, those which they may be able to perform and those they can perform with help. The teacher then mediates in scenarios where students are expected to perform tasks which they would not be able to perform under normal circumstances. Scaffolding therefore grants students an opportunity to interpret and perform tasks which could not be possible without guidance and assistance from the facilitator. Students are encouraged to construct meaning from their individual frames as the support by the teacher enables them to function at their level best whilst arousing individual curiosity and creativity.

At this juncture, the South African DoE faces a challenge that needs to be promptly addressed as experienced educators leave the system due to various reasons, some taking voluntary severance packages (VSP) and others early retirement. This then results in many schools being compelled to employ novices, including individuals with little or no pre- service teacher preparation. Many of these teachers are placed in schools where a large proportion of students come to class each day not particularly enthusiastic about what they are expected to do and often without the background knowledge and skills to connect with the day's lesson.

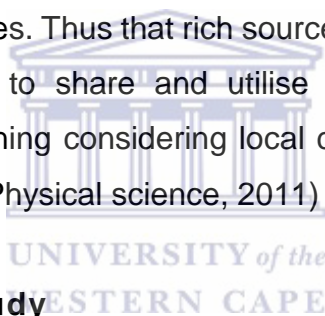
The growing realities are that increasing numbers of teachers have not had the opportunity to learn how to teach students who manifest commonplace learning, behaviour and emotional problems, and most teachers have to learn on-the-job how to teach such students. With the kind of challenges teachers face in their daily classroom environment, they are looking for alternative jobs other than being in front of students. Not all is lost, though, as there are teachers who are still enthusiastic about teaching and students willing to learn, who are joined everyday by novice teachers, who need to be motivated and supported in order for them to meet the expectations of students and curriculum delivery.

The researcher has been a physical science teacher for eleven years in the same setting where the research was done and also involved in various programmes intended to strengthen the teachers' inclination towards student performance improvement in physical science such as CAPS training, science expo's, school holiday teaching and physical science teaching intervention organised by DoE, district and Provincial officials. In addition, the researcher is currently doing a senior degree, M Ed (Science Education), which this project forms part of, under the guidance of the professional supervisor, hence the researcher has an open mind on how to conduct a fruitful mentorship programme. The mentoring design is intended to equip educators with skills in how to teach nature of science to high school physical science students using cooperative learning.

The physical science annual teaching plan (ATP) as designed by DoE has topics that progress from grade 10 to 12, which carry a greater weight, and which, when not understood well, greatly contribute to a decline in performance. In such cases, teachers need to acquire proper and working instructional strategies and instil cognitive processes in students. If students do not achieve the expected outcomes in a lesson, it is the duty of the teacher to change the teaching approach in order to improve student understanding; therefore teachers were equipped with the tested and proven approach so that they can exercise versatility in their daily teaching.

The impact of mentorship on the use cooperative learning in a physical science classroom for novice teachers in rural schools of the Eastern Cape has not been documented in academic writings. If this project yields positive results, such results

will be used as a barometer that teacher mentorship on cooperative learning can be used in a wider spectrum of the education sector. In support for this, Marzano, Gaddy & Dean (2000) confirmed that the strong effects of cooperative learning have encouraged some teachers to use the cooperative learning strategy for virtually every new learning situation. However, some psychologists such as Anderson, Reder, and Simon, as cited by Marzano et al, (2000) warn against the overuse of cooperative learning. These psychologists have noted that cooperative learning is being misused and frequently overused in education, arguing that it is misused when the tasks given to cooperative groups are not well structured and overused when it is used to such an extent that students have an insufficient amount of time to independently practise the skills and knowledge processing they need to master. For this reason, the research was done to manage such impressions whilst intending to embrace and appreciate the rich source of knowledge brought by individual students to the learning environment, as supported by Kusanda, Lubben, Campbell, Kandjeo-Marenga, & Gaoseb (2003) in their studies. Thus that rich source was put to good use, developed and exposed for students to share and utilise it amongst themselves, as the curriculum encourages learning considering local contexts, while being sensitive to global imperatives (CAPS- Physical science, 2011)



### **1.3 Context of the Study**

This study was conducted with participants from the rural schools of the Eastern Cape, considering that the performance in physical science is not consistent. It is evident that the physical science results are not taking a traceable improvement trend; hence this research was intended to contribute to the improvement of student performance by engaging physical science teachers and the physical science subject advisor on exploring the implementation of cooperative learning in everyday teaching. The researcher hopes for not only improved student performance, but also continued improved performance.

The 2013 matriculation results, as published by DoE (2014), improved to 78, 2% and the Physical Science pass percentage also improved. On the contrary, the Free State had an overall performance with 87,4% average pass percentage whereas the Eastern Cape – which has had problems ranging from the appointment of educators to infrastructure challenges - achieved 64,9% on average. The National Senior Certificate Examination school subject report in 2014 indicated that Physical Science

results were gradually improving even though there was no consistency in the improvement. Table 1 below tabulates the performance of students in physical science over a period of 4 years.

**Table 1: Physical science pass percentage for the year 2011 - 2014**

Matric Results Trend	2011	2012	2013	2014
NATIONAL	53.4 %	61.3 %	67.4 %	61.5 %
PROVINCIAL	46.0 %	53.0 %	64.9 %	51.5 %
DISTRICT	40.9 %	46.3 %	36.4 %	47.8 %

The picture displayed in Table 1 above could have been perpetrated by the complex matrix as alluded to by the DoE on the policy framework of teacher education and development. In this context the matrix in question would be of strategic importance for the intellectual, cultural, and moral preparation of the young minds of South Africa in complex conditions largely due to the pervasive legacies of apartheid.

A study done by Tumbo, Couper & Hugo (2009) concluded that the demographical and geographical spread of South African students is not proportionately represented in the universities. Their research was conducted in response to the study done by the Financial & Fiscal Commission in 2011 which revealed that only 7.7 % of the students in Quintile one schools who wrote the National Senior Certificate exams in 2009 passed (Czerniewicz & Brown, 2014). This therefore shows that even though the pass percentage for the Eastern Cape province ranges between 46 % and 64 %, only a few of those students passed, as many of the schools in the Eastern Cape are categorised as quintile 1.

Bearing that in mind, this research was conducted in the Eastern Cape, in a district where all schools are in quintile 1 category. The students in these schools are a quota of the previously disadvantaged South African communities but cannot be ignored. These categories are based on the community in which the school is situated. The schools in the poorest communities are categorised as quintile 1 and those in the least poor communities are quintile 5. To be in quintile 1 means limited to no access to community libraries, computer laboratories, internet access and many other educational facilities for both students and teachers. All South African public ordinary schools are categorised into five groups, called quintiles, largely for purposes of the

allocation of financial resources. Table 2 below shows how schools are categorised for the nine South African provinces with the Eastern Cape being the second province with many schools in quintile 1.

**Table 2: The National and Provincial breakdown table of the quintiles for 2014**

National Quintiles					
	1	2	3	4	5
EC	27.3%	24.7%	19.6%	17.0%	11.4%
FS	20.5%	20.9%	22.4%	20.8%	15.4%
GP	14.1%	14.7%	17.9%	21.9%	31.4
KZN	22.1%	23.2%	20.2%	18.7%	15.8%
LP	28.2%	24.6%	24.2%	14.9%	8.0%
MP	23.1%	24.1%	21.5%	17.7%	13.5%
NC	21.5%	19.3%	20.7%	21.4%	17.1%
NW	25.6%	22.3%	20.8%	17.6%	13.7%
WC	8.6%	13.3%	18.4%	28.0%	31.7%
SA	20.0%	20.0%	20.0%	20.0%	20.0%

This poses frustrations to both students and teachers and later perpetrates the dropping out of students from school and teachers looking for other opportunities. The article published in the City Press posted in January 2014 raised an interesting argument that the pass rate should not be measured by the matriculation pass percentage, according to the editor, because that deceives the nation. She claimed that the results should be traced four years before matriculation, that is, from grade 8 when the students were entering high school. She also argued the fact that by the time the students qualify to sit for their matriculation exams, a bigger percentage of the enrolled students from grade 8 cannot be accounted for in the schools at which they registered when they entered the FET phase, hence the South African School and Administration Management System (SASAMS) was introduced, which is an electronic integrated application that keeps records and reports on statistical analysis even on student enrolment.



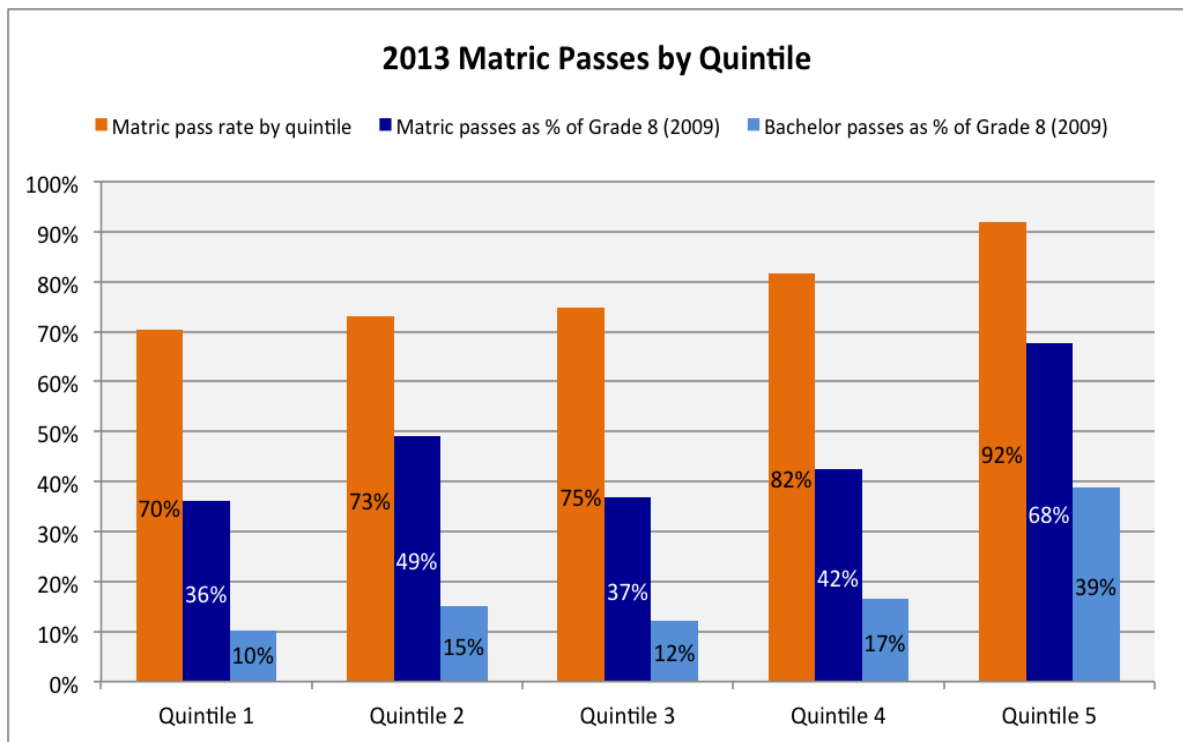


Figure 2: Pass percentage as per quintile for 2013

This graph shows that the students in quintile 1 lag behind in all forms of evaluation. For this reason, it shows that teachers in these parts of the scope have a struggle with the students' performance. In order to boost results, it is imperative to devise means and collective strategies to remedy the situation, hence this research was conducted with teachers who teach in quintile 1 schools.

Furthermore, the present curriculum is expected to assist stakeholders in redressing the imbalances of the past by ensuring that children acquire and apply knowledge and skills in ways that are meaningful to their own lives. In my opinion, that is nowhere near the situation remedy, without support given to teachers and allowing students to participate fully in their learning process. This research was thus envisaged to add value as one of the forms of support to the teachers.

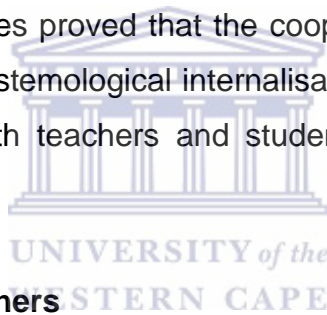
#### 1.4 Research Problem

The study done by Brüssow & Wilkinson (2010) engaged our thinking on learning facilitation strategies which they claim do not always address underprepared students ability to learn independently. In their study they ignored the percentage of prepared students exposed to a learning environment with limited learning skills. Seemingly their study had limitations. The aim of this research was to support teachers with best

practices on application cooperative learning and use of the knowledge of NoS in teaching science. This was also intended to engage student understanding pertaining to one of the physical science topics as they integrate cooperative learning strategy in the teaching of physical science. In addition, the aim is to evaluate the effects of the mentoring programme, for purposes of professional development strategies to improve performance and sustained student curiosity in scientific literacy.

Furthermore, it was evident that an agreement of 60.5 per cent (agree to strongly agree) was reached in this statement where respondents from Western Australia suggested that, although learning facilitation strategies existed, there was a lack of strategy in its implementation. That finding could then underscore the significance of investigating strategies, and their implementation, that encourage student independence. (Brüssow & Wilkinson, (2010).

The results of various studies proved that the cooperative learning strategy can be used extensively for the epistemological internalisation cause and improved student performance. However, both teachers and students still face various challenges which include:



#### **Challenges faced by Teachers**

- Need to prepare extra materials for class use
- Fear of inability to cover the intended content
- Lack of trust of students in their ability to acquire knowledge on their own
- Limited knowledge and familiarity with a cooperative learning approach.

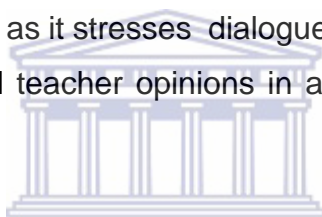
#### **Challenges faced by Students**

- Limited skills of working in a group
- Exposure to competitive learning
- Lack of understanding of the importance of individual contributions in a group.

Despite these challenges, one has to make an informed decision on which cooperative learning strategies promote a significant increase in student achievement and content literacy. Cooperative learning approach can ascertain student preparedness in exercising their social skills and working as a team. When this can

be achieved, it can inspire students in physical science learning. This can be possible if they know that they are not competing with anyone. The approach values student contribution to the learning of new concepts, thus influencing students to consider taking science at high school and pursuing a science-related career, as there are limited numbers of Black South African science graduates.

The review of the NCS curriculum into CAPS has led to teachers reverting to rote learning due to being told what to do in class and the time-frame restrictions which generally lead to imparting knowledge without taking into consideration how long that knowledge will last with the student. This somehow subjects teachers to a situation where they will teach, finish the prescribed work, and start from the beginning in the name of revision as students may have forgotten most of the work they had been taught. The constructivist theory as understood by Mathews (1993), stress student engagement in learning. He further notes the importance of understanding students' current conceptual schemes as it stresses dialogue, conversation, argument and the justification of students' and teacher opinions in a social society, in order to teach effectively.



In consideration of the cooperative learning facets, the study explored the fruitfulness of the mentoring programme for physical science teachers in enforcing meaningful discussions after creating such sets of circumstances. Student learning schemes were integrated with the student environment and the knowledge he/she brings from home that would enable them to internalise and grasp the concepts better. Most students tend to relate to new concepts if they engage in discussions until scientific misconceptions change to accepted conceptions. More so, students are able to internalise new knowledge if discussions are in their home language.

Along with improved performance as students solve scientific problems in collaboration, they acquire interpersonal skills and how to work in teams. Students are taught skills of communication, leadership and conflict management during the early stages of cooperative learning sessions.

## 1.5. Research Question

Given the research problem described above, the following research question was addressed in this study.

### *Main Research Question*

To what extent can cooperative learning (CL) enhance the understanding of nature of science (NoS) to advance the scientific literacy levels of secondary school physical science students?

### *Sub-Research Questions*

- 1 What is the teachers' knowledge of NoS and to what extent is NoS used as an instructional method for the understanding of science concepts?
- 2 How was the Cooperative Learning programme implemented to enhance teachers' understanding of NoS?
- 3 How did teachers implement cooperative learning when teaching NoS in their physical sciences classes after the intervention programme?
- 4 What were students' perceptions of the instructional method implemented by their teachers in their class?

## 1.6 Significance

This study addressed how teachers teaching in rural schools can be equipped in order to broaden their teaching skills by tapping into their understanding and interpretation of nature of science and enabling them to incorporate their strengthened understanding of cooperative learning in their everyday teaching of physical science for effective learning. For learning to be effective, it has been proved that it is not only about how teachers teach but also the alignment of the taught knowledge to the existing knowledge frame of individual students. It was then important for this research to include cooperative learning as a tool to investigate such knowledge frames in order for the programme to be seen as effective.

If this research yields positive results in terms of critically applying the skills gained from the mentoring programme and a trend of improved student understanding during and after the co-teaching process, it could influence a wider scope of directly or

indirectly involved audience, the researchers, practitioners (teachers), policy makers and special populations- students and parents. In the case of researchers, they could build on it for further research. Practitioners could use the same strategy in their respective schools for the improvement of student performance and thereby affirm to parents that the knowledge they impart to their children has a greater impact on their children's education.

The research might well inform the policy makers about the importance of supporting teachers with the development and strengthening of NoS knowledge and the implementation of cooperative learning strategy for improved student understanding of scientific literacy, especially students from rural areas, so that they can be competent in regard to the demands of the current physical science curriculum.

### **1.7 Limitations of the Study**

The number of teachers who participated in the research covers a small percentage of the teachers teaching in the same conditions, and the schools which were involved in the co-teaching practice also constitute a small percentage of the overall population of schools in this particular district. The teachers who took part in the mentoring programme had to contemplate about real classroom behaviour as they had to apply the lessons learnt from the workshop due to time constraints in the case of students adjusting to change from the strategies previously used in their science classrooms. The group that took part in the programme felt uneasy with extending the learnt lessons to their fellow colleagues as they claimed to be new in the field and were sceptical of how their involvement and contribution would be received by their fellow colleagues who have been in the system for a longer period. The number of teacher participants against the total population of the teachers teaching physical sciences in the district could make it difficult to generalize on the research findings

### **1.8 Structure of the Thesis**

The thesis is divided into chapters and they are outlined as follows:

#### Chapter 1: Introduction

This chapter provides an introduction to the study by presenting the background and context of the research. The details on the rationale of the study is also detailed for purposes of justification and contribution to literature.

## Chapter 2: Literature review

This chapter provides the theoretical framework that underpins this study, exposes and reflects on the studies done by other researchers on the same and related topics.

## Chapter 3: Methodology

This chapter tables the data collection method that was used in this research providing the structure and the detailed guide on how the data collection instruments were used. The chapter further provides the guide on how data will be analyzed as per each instrument used when the data were collected.

## Chapter 4: Findings

In this chapter the statistical results obtained in the testing of the research questions are presented and described. Data are presented and described according to the significant findings.

## Chapter 5: Discussion

The collected data are discussed, giving detailed deductions made from the findings. This is where the data were aligned to research questions so that implications and recommendations can be crafted.

## Chapter 6: Conclusion and Recommendations

The conclusion on the research findings is displayed in this chapter. This part of the research shows whether the assumptions were positively demonstrated or not. Recommendations with regards to the research findings were positioned here.

### **1.9 Conclusion**

This chapter introduced the background and context of the research problem and the research question. The following chapter provides the theoretical basis for the research through the theoretical frameworks and a review of literature directly and indirectly linked to this research.

## CHAPTER 2

# LITERATURE REVIEW

### 2.1 Introduction

This chapter introduces the theoretical frameworks which underpin this study. These theoretical frameworks include Pedagogical Content Knowledge (PCK), constructivism and cognitive theories that are directly applied to cooperative learning. It also provides a review of relevant literature that examines the framework for teacher knowledge of the content subject by engaging literature on nature of science, the use of cooperative learning and their contributions to the learning of physical science specifically and scientific literacy growth in general.

### 2.2 Theoretical Framework

The context of this study is theoretically founded and underpinned by three theories, pedagogical content knowledge (PCK), constructivism and theories on cooperative learning including social interdependence, cognitive-developmental and social-cognitive theory.

#### 2.2.1 *Pedagogical Content Knowledge (PCK)*

Shulman (1986) refers to pedagogical content knowledge (PCK) as an approach that deals with the grounded knowledge of effective instructional practices pertinent to specific content areas. In accordance to the claims made by Shulman (1986), Ramnarian and Schuster (2014) reiterated that successful science teaching demands not only good content knowledge but also knowledge of how to transfer that knowledge using appropriate teaching approaches for specific topics and particular groups of students. The approach for this study is grounded in the importance of understanding and translating nature of science, as this study focused on developing teachers in practical engaging of their science knowledge and relevant instructional practices when teaching physical science. This was done in order to suppress the overwhelming teaching frustrations in science learning. Most of these frustrations are perpetrated by the conditions under which teachers teach which later result in poor student performance.

PCK exists at the intersection of content and pedagogy and is concerned with the representation and formulation of concepts, pedagogical techniques, knowledge of what makes concepts difficult or easy to learn, knowledge of students' prior knowledge and theories of epistemology. It also involves knowledge of teaching strategies that incorporate appropriate conceptual representations, to address student difficulties and misconceptions and foster meaningful understanding. Furthermore, it includes knowledge of what the students bring to the learning situation, knowledge that might be either facilitative or dysfunctional for the particular learning task at hand. This knowledge of students embodies their strategies and prior conceptions; both from being naive and instructionally produced. The probabilities of student misconceptions are mainly about a particular domain and potential misapplication of prior knowledge.

Establishment, development and growth in the PCK concept means achievement of the basic education standards for various education systems. The diagram below is used not to exaggerate the value of PCK but to elicit every teacher's will to want to endeavour in growing one's PCK particularly in the science field.

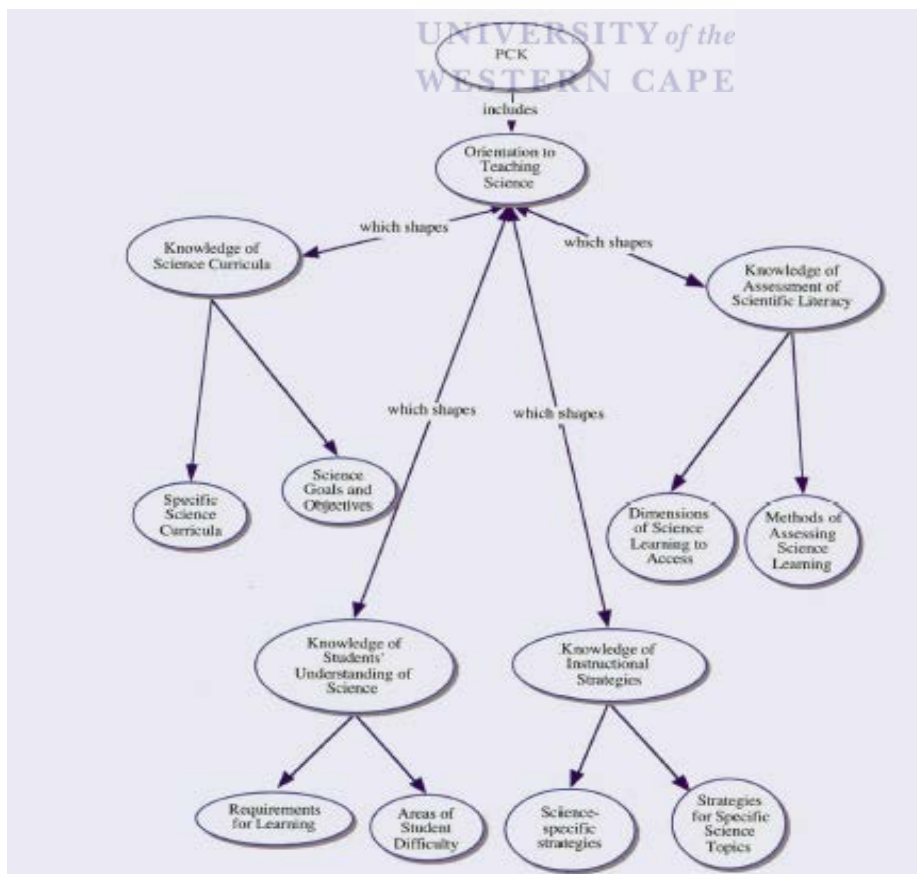


Figure 3: Components of pedagogical content knowledge for science teaching.



Figure 3 shows how PCK links the aims and objectives of the curriculum and attainment of content. This was later used during the mentoring programme and practical lesson presentation in the classroom.

Shulman (1986) highlighted a gap in educational research in which the importance of the content knowledge was overlooked. In that paper he advocated that content knowledge is more detailed than knowledge of the mere content. In elaboration, he claimed that it should be viewed also as being in a position to explain why a body of knowledge is regarded as acceptable, why it is worth knowing and its relations to other schemes both within and outside the discipline, in theory and in practice. In his deliberations, he further argued that a prepared teacher whose content knowledge is of acceptable standard knows not only that a certain body of knowledge is true or exists, but is able to justify why it is so and understands the circumstances under which that particular knowledge can or can no longer be asserted.

For a teacher to hold such value for the subject in the science discipline, the teacher must somehow have an understanding of NoS. This does not have to end with the teacher but is also imperative that students understand the evidence for current beliefs about natural phenomena, and should know the evidence that has led to those beliefs, and, just as with “traditional” subject matter, they should realize that perceptions may change as additional evidence is collected or the same evidence is viewed in a different way.

Shulman also pronounced the assumption that when teachers begin teaching they are in possession of some expertise in the content they teach, though he claimed that these assumptions may be unfounded. However, the consequences of varying degrees of subject matter competence and incompetence have become a serious topic. This research was conducted in accordance with Shulman’s assumption as it dealt with the transition from expert student to novice teacher, which was the crucial exercise for successful university students to transform their expertise in the physical science subject matter as they had proven at university, into a knowledge frame that high school students can link to their knowledge and conceptualize. The researcher also reviewed different literature on PCK which revealed how PCK can be an important aspect in a physical science classroom for the better understanding of the subject matter.

Research shows that overlooking the students' views of the topic dealt with in a lesson may lead to the unawareness of students' misconceptions. Furthermore the failure to take time for students' views can be linked to the teachers' expertise in a subject being the source of difficulty in teaching and learning as it reveals the teachers' lack of content knowledge (Halim & Meerah 2014). From their findings, PCK was dependent on the teachers' understanding of the content and they concurred that continuous teacher development in PCK was crucial, especially to the teachers who offered subjects outside their specialisation, as they were found to be perpetuating incorrect knowledge to students. During the time when this research was done, there were traces of the need for pre-service and in-service development as teachers involved would argue about how they were taught at their different training institutions in tackling particular aspects in the physical science syllabus. This showed that novice teachers had hoped to deliver the content in the manner in which they were taught, not considering other factors surrounding their teaching, factors like students' misconceptions and how to deal with them.

Wischow, Bryan and Bodner (2013) argued that research has shown that teachers undergo significant PCK growth and change during the induction phase of their teaching careers, which speaks to pre-service training. After examining different studies done on PCK, they concluded that the studies confirmed that content knowledge is critical in building PCK for teaching science, and teachers are able to advance their PCK and subject-specific PCK through purposeful learning experiences, such as student teaching and professional development, particularly when they are encouraged to reflect on their practices.

PCK is a transformation of knowledge for teaching and a teacher's understanding of how to help students grasp a particular subject. It is the amalgam of teacher content and pedagogical knowledge. There are two predominant strands of PCK studies in the science education literature: those that examine the developing PCK of pre-service for novice teachers and those that codify and describe the well-developed PCK of expert, experienced teachers. In order to bridge the gap between developing and developed PCK practitioners, team teaching and constant in-service interactions of teachers with content knowledge should be promoted. Studies that have

investigated PCK of pre-service teachers have described many of the difficulties that new teachers face in applying their content knowledge in the classroom.

The researcher believed that if teachers applied nature of science logically and constructively, it could address PCK elements as highlighted earlier and develop teachers' PCK so that misconceptions and misapplications could be addressed at a stage of discovery and, in the process, validate scientific laws and theories and enhance scientific understanding.

### *2.2.2 Constructivism Theory*

Constructivism is an active and social educational approach which is encouraged by, among others, problem-based and exploratory learning. In contrast with content-focussed pedagogy, constructivism is a cognitive learning theory that draws upon internal mental processes activated during learning (Turkich, Greive & Cozens, 2014). Piaget's theory identifies four developmental stages and the processes by which children progress through as they learn. Of the four stages, this research focused on the formal operations stage. The four stages are:

*Sensorimotor stage* (birth – 2 years old): The child, through physical interaction with his or her environment, builds a set of concepts about reality and how it works. This is the stage where a child does not know that physical objects remain in existence even when out of sight (object permanence).

*Preoperational stage* (ages 2-7): –At this stage the child is unable to conceptualize theoretical aspects hence requires concrete physical situations so as to make meaning.

*Concrete operations* (ages 7-11): As physical experience is developing and established, the child starts to conceptualize, creating logical structures that explain his or her physical experiences. Abstract problem solving is also possible at this stage, for example, arithmetic equations can be solved with numbers, and not just with objects, and thence abstract scientific concepts can be interpreted.

*Formal operations* (beginning at ages 11-15): During this stage, the child's cognitive structures are like those of an adult and include conceptual reasoning leading to scientific epistemological insight.

As this research was administered, careful acknowledgement of the fact that it was not focusing only on participants in the formal operation stage as Piaget suggested, but also involved adult (teacher) participants. These two groups were brought together by the claim that students at the formal operations stage had cognitive structures similar to those of adults, hence adult participants had to be aware of this, so that when they interact with students in their classrooms, they should expect knowledgeable and highly reasoning students, hence they need to be fully prepared for their lessons and able to accept diversity. Teaching that is consistent with the theory of constructivism involves the construction of knowledge by social processes, interactions with the environment and self-reflection, accompanied by a growing complexity of linkages between information, experience and peer interaction (Krause, Bochner & Duchesne 2003). This notion could also be derived from the studies done by Vygotsky (1962) as he alluded to the importance of the zone of proximal development (ZPD), a social component, which he claims to be the distance between a child's independent learning abilities and the learning that is guided, or from a more knowledgeable body. In more detail, Moll (1990) explained that by raising the notion that a student who is loaded with an idea will evolve to that idea in a ripe social setting, meaning that the guided learning should not be in isolation, but rather should take consideration of the student's independent learning abilities.

WESTERN CAPE

### *Classroom Implications*

Constructivist classrooms are diverse due to the fact that the teachers have to take into consideration the culture of individual students. The teacher's role of building an environment that allows children to make choices is done through learning centres and therefore constructivist classrooms tend to be noisy. Constructivist classrooms are entrenched in an active learning process and the belief that knowledge is constructed by the student and not transferred from the teacher to the student, and where the teacher is a facilitator or mediator in learning, as drawn from the work of Vygotsky, who emphasized the role of social interaction in which an expert guides a novice through a task to ensure that the student acquires higher level skills and who observes the student and looks to guiding rather than enforcing rules. In this study, students were allowed to actively engage with their own conceptual understanding and interact with peer understanding, which can be associated with positive interdependence.

Considering the teacher role as a facilitator, teachers were encouraged to note the following within the classroom:

- *Focus on the process of learning, rather than the end product of it.*
- *Use active methods that require rediscovering or reconstructing scientific truths.*
- *Use collaborative, as well as individual, activities.*
- *Devise situations that present useful problems, and create disequilibrium in the child.*
- *Evaluate the level of the child's development, so suitable tasks can be set.*

The main reason for the mentor to emphasise what teachers had to focus on was to maximise the benefits of the theory and minimize what Deutsch (1949) highlights as causes of failure. He posited two factors, *negative interdependence and no interdependence*, which, when examined closely, are more competitive than cooperative. According to Deutsch, negative interdependence exists when there is a negative correlation among individuals' goal achievements; individuals perceive that they can obtain their goals if and only if the other individuals with whom they are competitively linked, fail to obtain their goals. This kind of interaction results in oppositional or contrient interaction, where an individual conducts himself or herself in a manner that advantages him or her, but disadvantages others' efforts to complete tasks in order to reach their goals. The second form of interaction, which is no interdependence, exists when there is no correlation among individuals' goal achievements and individuals perceive that the achievement of their goals is unrelated to the goal achievement of others, hence they cannot contribute towards attaining of goals by others. In contrast, the basic premise of social interdependence theory is that of the manner in which participants' goals are structured, which will determine how they interact, and their interaction pattern determines the outcomes of the situation.

### *2.2.3 Theoretical Approaches to Cooperative Learning*

#### *2.2.3.1 Cognitive Developmental Theory*

According to Johnson and Johnson (2015) cooperation is a cognitive-developmental theory, which has been broadly dealt with by different, well known researchers, Jean

Piaget, Lev Semenovich Vygotsky, David Johnson and Roger Johnson, whose work is being widely used for further research studies. Cooperation in the Piagetian tradition is focussed at developing the individual's intellect by encouraging him or her to reach consensus with others who hold different perspectives about the answer to the same problem. A certain level of knowledge is demanded in order for a person to identify with certain body of knowledge. Therefore, for students to be able to engage in discussions about a certain knowledge, they need to be equipped with skills in how to engage others in a discussion.

Piaget's and Vygotsky's theoretical understanding argue that when individuals engage with one another in the social environment, outcomes in students' learning become more positive. Extending this idea is Tran (2013) who advocates that the instructional pedagogy needs to be personalized to help students have more opportunities to interact with others in learning tasks. If teachers are to be true facilitators of learning, then they have to know their students well. Teachers are therefore urged to first assess the students' current level of cognitive strengths and weaknesses in order to apply appropriate teaching approaches. Through assessment, then, their level of development can also be determined.

Vygotsky (1962) argues that knowledge is a social phenomenon, constructed from cooperative efforts to learn, understand, and solve problems, which can be accomplished while working in cooperation with older individuals or more capable peers. According to Vygotsky, a person will grow intellectually only when working cooperatively and, also, individual mental functioning is an internalized and transformed version of the accomplishments of a group, hence the time students' work alone should therefore be minimized.

A central aspect of cooperation, according to cognitive-developmental theory, is conflict among ideas or controversy (Johnson & Johnson 2015). Constructive controversy theory (Johnson & Johnson, 1979, 2007, 2009) posits that being confronted with opposing points of view creates doubts and disequilibrium, uncertainty, or conceptual conflict, which creates a search for more information and a reconceptualization of the issue, and this results in a more researched, refined and thoughtful conclusion. The key steps of constructive controversy are: organizing what is known into a position; advocating that position to someone who is advocating an

opposing position; attempting to refute the opposing position while rebutting the attacks on one's own position; reversing perspectives so that the issue may be seen from multiple points of view simultaneously, and, finally, creating a synthesis with which all sides can agree. This is also in line with Piaget's and Vygotsky's cognitive development ideology.

However, Bandura (2000) advocates for social cognitive theory from which he views cooperation as the shared belief of group members in their collective ability to work together and achieve desired results, securing what they cannot accomplish on their own. Due to the heterogeneity of the groups, disagreement and debate among group members need to be managed constructively; students should be encouraged to support each other's efforts to achieve and if they cannot be managed, that can defeat the purpose of the strategy. In order to minimize disagreements and promote effective collective contributions, groups must be made smaller. This will enable students to be able to gain confidence and express their views with ease, hence enabling peer tutoring. In this setting, even when disagreements and debates arise, students will be able to perform investigation in the topic at hand, thus developing research and other related skills.



However, Sharan and Sharan (1976) argued that the group investigation method promoted higher levels of cognitive functioning than peer tutoring. The results from their study showed that not only did the children in the group investigation classes achieve more, academically, than their peers in whole class settings, but also they were more interactive in their groups, more focused on the problem they were trying to solve, and used more sophisticated language strategies. Sharan and Shachar (1980) proposed that this was witnessed because the students who were involved in the cooperative groups had opportunities to practise using different verbal and cognitive strategies they had heard their teachers use as part of the teaching and learning process in their classrooms. However, the students in the whole class groups may have heard the same verbal and cognitive strategies but, because they did not have the opportunities to put it into practice, these strategies may not have had the same impact. In essence, children need opportunities to interact with each other if they are to develop an understanding of their world and find new ways of expressing their thoughts and feelings. This is also upheld by Bandura (2000) as he claims social-cognitive theory places cooperation at the centre of a community of practice, whereby

a student will cognitively rehearse and restructure information as well as explaining the material being learned to a collaborator, through what he calls key behaviours, which are modeling, coaching, and providing conceptual frameworks that result in an understanding of what is being learned.

### 2.2.3.2 Social Interdependence Theory

The basic premise of the social interdependence theory is that the way in which goals are structured determines how individuals interact, and interaction patterns create outcomes (Deutsch, 1949). A strong relationship has been found between cooperative learning and the social interdependence theory (Johnson & Johnson, 2005), and the theory is relevant when an individual's goals are accomplished with the contribution and influence of the actions of others. Furthermore, social interdependence is the interaction that exists when individuals share common goals and each individual's outcomes are affected by the actions of the others (Johnson & Johnson 1989). This perspective holds that students help each other learn because they care about the group and its individual members, and come to derive self-identity benefits from group membership (Slavin, 2011).

Of the three types of social interdependence, positive, negative and non-interdependence, each type of interdependence results in certain psychological processes. Johnson & Johnson (2005) cited Deutsch's idea of psychological processes as associated with *substitutability* (the degree to which actions of one person substitutes for the actions of another person), *inducibility* (the openness to being influenced and to influencing others) and positive *cathexis* (the investment of psychological energy in objects outside of oneself, such as friends, family, and work), which shows value and benefits of this theory in a broader social aspect. He further claimed that positive outcomes of social interdependence are identified as effort to achieve, positive relationships and social support, psychological health and self-esteem, and greater performance. In the absence of this kind of interaction it can be deduced that an individual is detached from others, thereby creating non-substitutability, cathexis only to one's own actions, and no inducibility, or resistance to completely shared goals.



Various studies have shown that in cooperative situations performance is constructed in terms of

- achievement and productivity,
- long-term retention,
- on-task behavior,
- use of higher-level reasoning strategies,
- generation of new ideas and solutions,
- transfer of what is learned within one situation to another,
- intrinsic motivation,
- achievement motivation,
- continuing motivation to learn, and positive attitudes toward learning.
- Co-operative learning was thus confidently used in this research.

### **2.3 Why should we teach NoS?**

Vygotsky's work as edited by Cole *et al.*, (1978) talks of *actual development level* as mental development in terms of what the child can do and has been seen doing and the *zone of proximal development (ZPD)* as what the child can be expected to do in the near future due to processes in a state of formation. These are in their initial stages of maturity and development provided the developmental conditions are maintained. According to him these conditions would be guidance, demonstrations, leading questions and interaction with peers and experts.

As the students' progress in mental development, the explicit knowledge of NoS by the teachers, which should be taught and form the basis of scientific understanding, will enable them to outgrow the stage of ZPD and yield actual development. However, in the paper presented at the Annual Meeting of the National Association for Research in Science Teaching by Lederman (1986), the results indicated that simply possessing valid conceptions of nature of science do not necessarily result in the performance of those teaching behaviours which are related to improved student conceptions. On the contrary, the results of this investigation could not derogate the importance of a teacher's conception of nature of science. According to his assumptions a teacher must have at least a working knowledge of what he or she is expected to teach.

Another study done by Lederman (1999) with experienced teachers has indicated that teachers' beliefs about the importance of NoS and their intentions to teach NoS are critical factors determining classroom practice. Hence this study intended to raise awareness of the importance of NoS and the benefits it could have when taught to secondary students. In consultation with Shulman's and Lederman's findings, the researcher had her own assumptions, that the body of knowledge that teachers have is not enough to yield actual student development if it is in isolation without being linked to the processes of learning as alluded to by Vygotsky.

The actual definition of NoS has been a lengthy debate hailing from Herron (1969), whereby he claimed that there was no sound and definite description in existence concerning NoS and science structure. Other researchers such as Laudan (1981) claimed that there was no well-confirmed general picture of how science works, until such time when Lederman (1992) noted that nature of science is neither universal nor stable. In agreement with Lederman, McComas (1998) argued that the content of nature of science will always be continuous in one way or the other and the views related to topics which can be regarded as most important for scientifically literate society could not be associated with controversy. He also concurred with other researchers when acknowledging a lack of complete agreement with regards to what science is and how it works. This then meant that even after numerous education reforms, there is still a greater need for science teachers, students and curriculum designers to facilitate NoS so as to curb the increasing numbers of scientific illiteracy. Due to this ambiguity in describing what NoS is during those early days of its inception in science education, many societies are not scientifically aware and are scientifically illiterate.

Lederman (1986) described NoS as the values and assumptions inherent to scientific knowledge which are tentativeness, parsimony, empirically based and amoral. In this research these values were closer viewed with respect to the South African context and physical science curriculum as outlined in the physical science Curriculum Assessment Policy Statement (CAPS) document for the current curriculum. This document outlines how science and society are interlinked to an extent that it acknowledges the fact that the knowledge that the society possesses has been passed on through generations and has been a source of many innovations and developments including scientific developments. The fact that some of the aspects

held by society can even be explained scientifically therefore means that the knowledge which students have as a result of the informal learning through an indigenous framework cannot be forgotten during physical science lessons.

However, not every aspect of indigenous knowledge can be regarded as scientifically acceptable. Therefore science teachers become obliged to possess a certain degree of nature of science which, when taught to students, allows them to reason and test the plausibility of their existing knowledge and thus minimize misconceptions. The manner in which this curriculum is crafted makes it clear that the government has clear intentions with regard to the envisaged physical science student in the FET phase. This is clarified by the aim of teaching science which is intended construction and application of scientific and technological knowledge; an understanding of nature of science and its relationships to technology, society and the environment in order to promote knowledge and skills in scientific inquiry and problem solving. The South African physical science curriculum is categorized into six main knowledge areas which inform the subject:

- Matter and Materials
- Chemical Systems
- Chemical Change
- Mechanics
- Waves, Sound and Light and
- Electricity and Magnetism.



With all the six categories, students are likely to hold a certain actual development which is knowledge of what they can do without anyone's assistance in a classroom activity. Then the teacher is expected to establish what they know and can perform without assistance in each aspect of the curriculum and build from that, bearing in mind their misconceptions and being ready to address them with plausible nature of science and thereby build student confidence. Having highlighted that knowledge cannot be transferred from one person to another, it is therefore imperative for every teacher to identify the lesson with the students' actual development so as to be able to work on ZPD.

In the absence of an acceptable degree of the physical science content knowledge, the likelihood would be that students' misconceptions cannot and will not be

challenged and that would jeopardize the government's intentions and hopes of promoting knowledge and skills in scientific inquiry and problem solving by the South African younger generation. There is a degree of confidence revealed by the paper written and presented by Naidoo & Govender (2010) in the eighteenth annual Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE) meeting which found evidence from their study that post-graduate science teachers who had undergone an Honours university programme with modules covering NoS issues in-depth held appropriate views and adequate understandings of nature of science. These teachers were more confident to teach NoS concepts in class. They also recommended that the Department of Education take it upon itself to encourage and fund more teachers to undertake this programme working in partnership with universities.

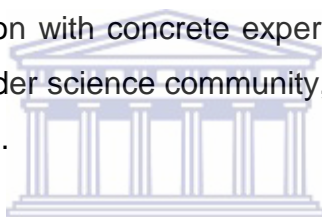
Having said all that, I would also emphasize the geographic consideration so that all students can have an equal right to be taught by equally competent teachers. Knowing that the majority of the students in the rural schools are black African children who have been marginalized and unable to access proper learning resources, it felt proper to undertake this project in order to test whether or not novice teachers' classroom practices could be affected to yield appropriate views of NoS in their students and contribute to their development with the aim to create space for growth and confidence to physical science students. Due to limitations of the study, I was able to tackle one topic in the FET phase which I used throughout the whole study.

According to Lederman (1998), the lack of an understanding of how scientific knowledge is derived and the implications the process of derivation has for the status and limitations of the knowledge, all students can ever hope to achieve is knowledge without context. He claimed that context is necessary for students to understand what the knowledge means, as he refers to that as equivalent to playing a game of chess without knowing the rules of the game. It therefore became imperative for this study to highlight what was meant particularly by nature of Science for this research as it hoped that the knowledge the students acquire, enables them to make informed scientific decisions. The emphasis of nature of Science in this study is on giving students an opportunity to understand not only what scientists know and have discovered but mainly how they know it. For teachers to be able to undertake this task

successfully, according to my assumptions, was through their willingness to teach NoS to the students in order to translate the acquired PCK on the topic dealt with.

## **2.4 Studies in cooperative learning**

According to Avery (2013), several key teaching strategies can enhance access to science, technology, engineering, and mathematics (STEM) in rural communities. Of those strategies, this research focused on three: the researcher advises to offer teacher place-based professional development programmes that work with a core group of mentor teachers who self-identify themselves as being committed to changing the way science is taught in rural settings by valuing and utilizing children's local and rural knowledge (LRK). In accordance with that, she spoke of scaffold content and pedagogy across grade levels and connects LRK with educational standards, which can enhance rural students' engagement in science. Thirdly, she advocated students' provision with concrete experiences that show them how their LRK connects with the broader science community, which can inspire rural students' STEM interests and pursuits.



With regard to the place-based mentor, the study explored the effect of a mentor in the improvement of science understanding by students after they have been taught using the skills gained from the mentoring workshop. During the teacher empowerment on how to implement nature of science inclusion in the teaching of physical science in the secondary school students, teachers were also encouraged to commend students' efforts in exposing science related issues that are learnt through LRK. This research had intended to induce science learning through the use of cooperative learning in rural schools, giving students an opportunity to internalise science concepts through cooperative learning paradigms.

The efforts by departmental stakeholders has shown that switching from traditional teacher-centred approach to active or engaged instructional approach is a global concern. Countries world-wide have designed policies on teacher standards that are to be upheld in the teaching fraternity. The most successful education systems in the world are characterized by quality standards that address the student needs as the student's achievement can be effected only by the quality of teaching they receive, which is why the priority is on the importance of classroom practice, content

knowledge and pedagogical knowledge. The England Department for Education (2014) standards, among many, include:

- Expectations for the professional practice and conduct of teachers and defines the minimum level of practice expected of teachers in England.
- Teachers observing one another's practice in the classroom and learning from other professionals. Observing teaching and being observed, and having the opportunity to plan, prepare, reflect on and teach with other teachers can help to improve the quality of teaching.
- Reflection from the feedback given from their teaching by colleagues and from observing the practice of others in order to improve their own practice.

These standards are supposed be used by schools to assess the extent to which newly qualified teachers can demonstrate their competence at the end of their induction period and can be used by individual teachers to review their practice and inform their plans for continuing professional development.

On the other hand, the South African Department of Education in the Government Gazette (2007) on teacher development reported on the objectives of the policy framework for teacher education and development which are:

- Equip the teaching profession to meet the needs of the democratic South Africa and bring clarity and coherence to the complex matrix.
- Enable teachers to continually enhance their professional competence and performance.
- Build a community of competent teachers dedicated to providing high quality education with high levels of performance.

The efforts made by the government in student and teacher development in all science related programmes, still continues in order for teachers and students to be capacitated. The Head of the Southern Africa Large Telescope (SALT) collateral benefits programme, summarised the work of the outreach department at the South African Astronomical Observatory (SAAO) during his conference presentation, stating that they had been very successful in training and supporting teachers and curriculum advisors in the teaching of Natural Science and particularly the theme 'Earth and Beyond' through programmes such as the national astronomy quiz. This is believed

to inspire curiosity and critical thinking among students and spread career information pertaining to astronomy and related science. This therefore calls for the demand of competent educators in order to deliver the content using the best fitting pedagogy.

May and Doob (1937) pointed out that people who cooperate and work together to achieve shared goals happen to be much more successful in attaining their outcomes and do so sooner than those who burden themselves by working independently in completing the same goals. However, their research received criticism from Jonson & Johnson (2005) as lacking conceptual clarity on the origins of cooperation and competition.

Many science educators have made efforts to develop and implement pre- or in-service teacher programmes to improve science teaching and learning (Supovitz & Turner, 2000). However, criticism of traditional teacher programmes highlighted by Driel, Beijaard, & Verloop (2001) as inadequate and ineffective in improving science teaching and learning in schools encourages innovations for concerned practitioners.

In support of the recommendations made by teachers, replacing a traditional method by instructional approaches that encourage active student participation, teachers were mentored in the use of cooperative teaching and learning when teaching physical science. Stears and Gopal (2010) argue that individual work accommodates divergence while cooperative or collaborative learning enable opportunities for convergence. This perspective holds that students help each other learn because they care about the group and its members, and come to derive self-identity benefits from group membership (Slavin, 2011). In this research, teachers were exposed on how to use cooperative learning when teaching physical science and the importance of collaboration as practitioners in order to share knowledge and skills learnt in the mentoring programme.

A strong relationship has been found between cooperative learning and the social interdependence theory (Johnson & Johnson, 2005). Why is it crucial for teachers to possess skills in teaching using active learning? Are they crucial for their empowerment or their students'? Contrary to the claims made by Slavin, The fact that students were not thrilled since they had to be fully engaged through all the learning

processes, skilful application of cooperative learning strategy was of great importance.

Does that mean teachers should give up on the introduction of the student-centred instructional approach? Levin (1948), as cited by Van Dat (2013), proposed differently. He argued that states of tension motivate a person's behaviour and as desired goals are perceived, actions are motivated by this tension to achieve the desired goals.

Science teaching needs to be planned and organized to encourage students to participate in various active activities. Therefore, it was emphasized that students can connect what they learned in science class with other subjects or everyday life through active cooperation and communication using various learning strategies and materials. In this research, teachers are more likely to be interested in the programme due to the pressure from the DoE putting forward expectations (goals) for every teacher, to enable students to know the content and progress them to the next class.

In an effort to improve teacher learning, science educators have aimed to expose teachers to effective, evidence-based, and up-to-date educational theories and teaching strategies through many teacher-training programmes. These efforts were intended to encourage teachers to apply what they have learned to their teaching practice. However, if such effective teacher-training programmes are not based on and closely connected to everyday practical teaching, these programmes will be ineffective and thus defeat the intention.

Deutsch (1949) developed Levin's social interdependence theory by discussing the relationship between the goals of two or more individuals. Deutsch argued that social interdependence might be both positive and negative. It may be positive when individuals work cooperatively to attain their shared goals, and it may be negative when individuals compete to claim who attained the goals.

In 2006 the National Policy Framework for Teacher Education and Development in South Africa (NPFTEDSA) agreed on the notion that a close relationship with new recruits in the Initial Professional Education of Teachers (IPET) routes to a qualification. It states that new recruits to the teaching profession will be able to enter



the teaching profession by qualifying in either of two ways: Complete a B.Ed. degree with 480 credits, at National Qualification Framework (NQF) level 7 and a practical component of 120 credits. The practical component may be undertaken in short periods during the programme, comprise an extended period of service during the final year with a structured mentorship programme, or be undertaken by student teachers or serving teachers in schools under supervision by a mentor. The experience and expertise of the researcher gathered over the period of service strongly supports that notion.

## **2.5 Instructional Systems of cooperative learning**

Systems involve relationships, conditions, processes, causes, effects and feedback. In this research the system highlighted below in figure 3 was used during the mentoring programme. In order to identify a system, we had to demarcate where one system ends and another begins. Generally, in education, an instructional system has to be identified in order to focus on bracketing out the learning system. Petrina (2007) used the instructional system in his research with intentions to highlight its scope and demonstrate how the components relationships. The same system was used in this research but for different intentions. This research focused on some system components and made those visible and left others invisible. In this research the instructional systems involved decisions related to what was taught, how it was taught and organized for learning, and how learning was encouraged. For analytical purposes it was necessary to identify what students and teachers did within the system as it was crucial to address individual components of the system. While there are components that are overlooked, the diagram below generally represents an instructional system from which the instructional planning unfolds quite procedurally, but not necessarily in the exact linear fashion as shown by Figure 4.

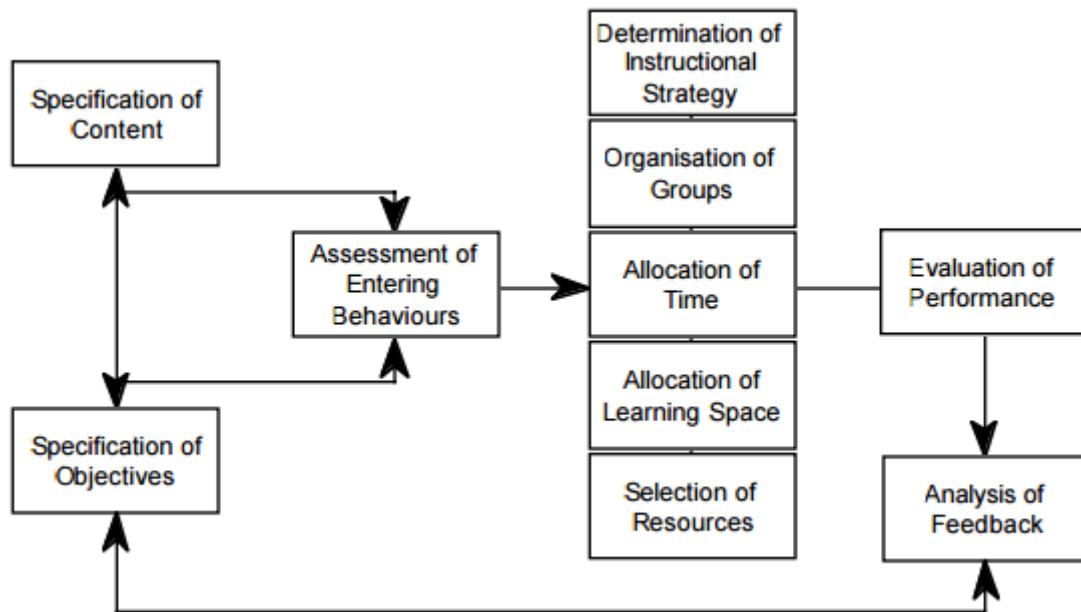
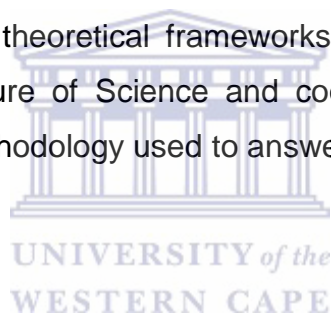


Figure 4: Instructional System

## 2.6 Conclusion

This chapter provided the theoretical frameworks that underpin the research and highlighted studies on nature of Science and cooperative learning. The following chapter will present the methodology used to answer the research questions.



## CHAPTER 3

# METHODOLOGY

### 3.1 Introduction

This chapter outlines the research methodology that was used in this study. It describes the research design, the sample to be used and provides the data collection plan that will be employed to collect the data. The causal factors for the selection of this sample and instruments are also outlined. It also explicitly shows the rigour in the research in terms of validity and reliability when collecting data in answering the following research question:

*To what extent can cooperative learning (CL) enhance the understanding of nature of science (NoS) to advance the scientific literacy levels of secondary school physical science students?*

### 3.2 Research Design

In this research project, the researcher used a mixed method approach with some elements of the action research in an attempt to explore how mentoring of physical science teachers in the effective use of cooperative learning can enhance their teaching for the sustained performance or improvement in physical science. Creswell and Clark (2011) argued that integrating methodological approaches strengthens the research design as the strengths of one-approach offsets the weaknesses of the other and can provide more conclusive and convincing evidence than mono-method approach studies. This study therefore used both qualitative and a quantitative methods.

As highlighted by different researchers, the use of the mixed method enabled the researcher to obtain integrated findings, complementary strengths and non-overlapping weaknesses. In this case the combination of the two methods complimented one another in improving quality of the research (Jonson & Christensen, 2012). The findings of this research from both research methods had similar trends which in return validated the choice of the mixed method for this particular research. The skilful use of this form of triangulation obtain a better, more substantive picture of reality; a richer, more complete array of symbols and theoretical concepts; and a means of many of these elements. The attempt to enrich them so as

to counteract the threats to validity identified in each method could be embraced, not to use it for the sake of its popularity. However, Fielding (2012) criticises the use of the research design due to it being fashionable as he claims that it is less likely to elicit the kind of thoughtfulness about data integration that inspires confidence in findings so the research makes a difference in the real world.

### *3.2.1 The quantitative approach*

A Pedagogical Learning for Scientific Literacy Questionnaire (PLSLQ) was designed and administered to teachers with the purpose of determining the teachers' understanding of cooperative learning as a tool to unpack the aims of the Curriculum Assessment Policy Statement (CAPS). The CAPS (2011) aims at ensuring that students acquire and apply knowledge and skills in ways that are meaningful to their own lives. In this regard, the curriculum promotes knowledge in local contexts, while being sensitive to global imperatives.

The (PLSLQ) was intended to establish whether teachers were using cooperative learning strategy in their physical science lessons. Furthermore the tool had to bring to light whether teachers have adequate conceptions of NoS. it was also imperative to the researcher to know whether teachers position their lesson in order to uncover their students' views of nature of science. In this questionnaire, the researcher incorporated nature of science, as this body of knowledge is regarded as the way of knowing science or the tool to explain scientific phenomena around us and the two cannot be separated. Quantitative approach was used to elicit information from the teachers as respondents in order to inform the structure of the mentoring programme, and from the students so as to enable the researcher to deduce whether or not there was a shift in terms of the impact the research can exhibit within the set scope. The reason why the researcher decided to use the quantitative method was due to the influence by various studies that used it and came with rich data. According to Muijs (2011), quantitative research is basically about collecting numerical data to explain certain phenomena. He further argues that there is a variety of phenomena of which, in its natural state, don't produce quantitative data particularly in education. However, data collected in this research, though in its natural state, was quantified and analysed using the quantitative approach.

The pedagogical approach that was explored could not have a positive impact on the student performance without relevant tools; hence the teacher content knowledge had to be considered in the programme. From this the researcher intended to generate numerical data which gave an indication of the number of teachers who upheld the use, held the understanding and implemented cooperative teaching when teaching physical science.

Even though this method would fail when used with intention to explore a problem in depth, it was purposely selected as the researcher wanted to gather information in breadth testing the hypothesis that novice physical science teachers may neither be using cooperative learning in order to enhance the teaching NoS, nor aware of the impact this could have in their everyday teaching and on the student performance.

### *3.2.2 The qualitative approach*

For the purposes of understanding the conduct of every day teaching in detail and to identify the meanings that those events have for those who participate in them and for those who witness them, the qualitative research approach was used as suggested by Erickson (2012). They further added that qualitative research in education is especially appropriate when intended to detail information about implementation, identify the nuances of subjective understanding that motivate various participants in a setting and to identify and understand change over time.

Furthermore the qualitative method that was used in this research is the oldest known method which is the case study. This is an in-depth study of individuals, groups or social settings or events with the hope of revealing and understanding aspects of concern to the researcher. According to Berg (2001), qualitative procedures provide a means of accessing unquantifiable facts about the actual people researchers observe and talk to people about their personal deductions. Thence, qualitative techniques allow researchers to share in the understandings and perceptions of others and to explore how people structure and give meaning to their daily lives. Researchers using qualitative techniques examine how people learn about and make sense of themselves and others.

Qualitative research is characterized by its aims, which relate to understanding some aspect of social life, and its methods which (in general) generate words, rather than

numbers, as data for analysis (Rotchford, Rotchford, Mthethwa. & Johnson, 2002). Rotchford *et al.*, (2002) also claimed that there are different sorts of questions that need answering, some requiring quantitative methods, and some requiring qualitative methods. However, qualitative method has received common criticisms which, among many, include small samples which are not necessarily representative of the broader population and its findings are said to lack rigour. In this research, qualitative research was used due to its effectiveness when working with a particular case and also the rich data it delivers when testing social- related aspects.

In order for the researcher to obtain rich data, the qualitative approach was used in conjunction with the quantitative approach for data triangulation purposes and intentions to minimize the biases, increase credibility and validate the results. The qualitative approach focused on the phenomenon that occurs in its natural settings with data analysed without the use of statistical measurement.

In this study, the researcher intended to uncover the extent to which the experience gained during the mentoring programme could be put into practice in order to advance the use of the cooperative learning when teaching NoS in a physical science lesson. Teachers were observed during the co-teaching classroom session in order to identify whether or not the elements of cooperative learning were put into practice and also that the lesson promoted the learning of NoS in a manner that benefits and enhances the students' understanding of physical science. This refers to the ability of the instructional method to endorse the use of local content whilst eliminating the misunderstanding and misconceptions in relation to the physical science concepts, also influencing the student scientific literacy and student performance. Thus, a video TAPE was used in order to uncover that information. This was also done to evaluate the strengths of team work among the teachers and to encourage teachers to engage with one another more if they found it working.

A case study method was used since the research covered a small scope of participants and the primary advantage for using the case study method is that it usually allows concentration on an issue, problem, or concern that is directly or indirectly related to the field of expertise (Wargo, 2014).

### **3.3 The research sample**

The participants in this research were physical science teachers from rural schools of the Eastern Cape and in a particular district. The physical science teachers would also have been teaching physical science for five (5) years or less. The research also involved physical science students from two different schools whose physical science subject teacher participated in the intervention programme.

A purposive sample of fifteen novice qualified teachers (experience of five or less number of years) teaching physical science in a secondary school in one district of the Eastern Cape was selected. All fifteen were given a questionnaire for baseline assessment of aspects related to: teachers being understanding of what their students think about science and their level of scientific literacy, teachers' knowledge of nature of science, students' views of NoS, and the extent to which teachers use cooperative learning when teaching physical science. Responses to the questionnaire were used to inform the researcher on the framework of the mentorship programme in order to integrate the theories and strengthen the rationale of the study. Of the fifteen issued questionnaires, seven of them were completed and returned.

The seven teachers who participated in the survey and whose questionnaires were completed and returned took part in the intervention programme in the form of a workshop. The intervention was informed by the responses from the questionnaire. On the day of the workshop three other teachers, who had not participated in the filling of the questionnaire, joined the programme. The total number of teachers was then increased to ten. At the end of the workshop which was stretched over three days, the treatment would not be tested without the actual application of the workshop practices. For the purpose of application of CL to enhance the teaching of NoS a non-probability sample of two teachers with the students they teach had to be selected.

A purposive sample of teachers who are not teaching grade twelve was going to be the extension of the treatment. During the time the researcher was seeking permission to conduct research the subject advisor requested that grade twelve students should not take part in the research as he felt that they would be disturbed. Therefore four participants who were only teaching grade twelve were excluded. The researcher was then left with five teachers in the position to teach and implement the outcomes of the workshop. The teacher who was teaching physical science for the

first time during the time when the research was conducted requested to be exempted as well as she claimed that she was not confident with physical science content. From the remaining four teachers, the researcher chose to have two teachers as it would be cost effective to visit the four schools and would be time consuming as the students still had to sign the consent forms. Two teachers volunteered and one teacher was teaching physical science in grade eleven and the other one was teaching grade ten. The teachers and the groups of students were from two different schools. There were forty six students from the grade eleven class and fifty students from the grade ten class; the classes were called group A and group B respectively. The table supplied below gives a summary of the sample.

**TABLE 3: Sample structure**

Technique	Respondent	Sampling	Criteria
Random	Teacher	7	Total population
Random	Teacher	7 + 3	Availability
Purposive	Teacher	2	Voluntary
Purposive	Student	96	Convenience

### 3.4 Data Collection Plan

In this research, data were collected with the aid of questionnaires and video table recordings. The research conducted involved an intervention programme, the effect of which was envisaged to be enriched by the co-teaching and by conducting a survey with students at the later stages of the research. Hence video-recording was crucial to enable the researcher to determine the successes and limitations of all the processes and thereby assess the progression of all the active participants. The layout of the methodology of this research is tabulated in Table 4 below. The study was conducted along four steps.

**TABLE 4: Summary of the data collection plan**

Research questions	Method	Instrument	Respondent	Data Analysis
Main research question	To what extent can cooperative learning (CL) enhance the understanding of nature of science (NoS) to advance the scientific literacy levels of secondary school physical science students?			



1. What are the teachers' knowledge of NoS and to what extent is NoS used as an instructional method for the understanding of science concepts?	Survey	Pedagogical Learning for Scientific Literacy Questionnaire (PLSLQ)	Teacher	Excel Spreadsheet and thick description
2 How was the Cooperative Learning programme implemented to enhance teachers understanding of NoS?	Intervention programme Video-taped Evaluation	Training Manual  Evaluation sheet	Teacher	Thick description  Excel Spreadsheet
3 How did teachers implement cooperative learning of NoS in their physical sciences classes after the intervention programme?	Observation Video-taped	Lesson plan	Teacher	Thick description
4 What were students' perceptions of the instructional method implemented by their teacher?	Survey	Practicum Review Questionnaire (PRQ)	Student	Excel Spreadsheet

Step 1: The researcher used a questionnaire for the teachers, which was meant to establish the teacher's knowledge of NoS and the extent to which CL is used as an instructional method for the understanding of the science concepts and scientific literacy. The questionnaire had a section that intended to elicit the use of cooperative learning in a science class. The aim was to inform the mentorship programme on which aspects of cooperative learning need to be stressed, as it address the main research question, that is, application of CL to enhance teaching of NoS in secondary school students to advance scientific literacy. This exercise would also contribute to the teachers' potential to maximise their scientific attributes towards advancing optimal opportunities. After this, data were analysed, and the intervention programme, in the form of the workshop, was conducted in the next stage.

Step 2: The structured intervention programme was undertaken with seven teachers who had filled in the questionnaire and by three other teachers who joined the workshop but do not part of data collection using a questionnaire. The intervention programme was structured to be a three day workshop and two days co-teaching lesson presentation exercise. These activities were all video-taped in order to be analyse later as the researcher was also a facilitator in the workshop. The structure of the workshop was in three phases. The first phase examined teaching strategies teachers use when teaching different topics in physical science with much focus on cooperative learning. Phase two dealt with the teacher understanding of NoS and how they can explicitly teach its elements when teaching physical science. Part of this phase incorporated the application of CL in these lessons. The third phase focussed on the importance understanding the students' views about a particular learning aspect so that teachers can facilitate learning by designing lesson presentations that suit their students. Analysis of this treatment administered to teachers was also used for purposes of the workshop evaluation, to inform the programme managers and relevant stakeholders for improvement.

Step 3: During this stage two lessons were presented and video-taped from different schools and different times. The aim was to the deliver a lesson that explicitly taught elements of NoS using CL and develop the students' scientific literacy. Other aspects specifically looked at included facilitating the conceptual understanding, evaluating students' views of NoS and uncovering students' conceptual phenomena. Results for this section were analysed using thick description.

In Step 4 a post- assessment tool in the form of a questionnaire for evaluation purposes regarding how the students perceived the lesson, with an aim to establish the effect, in terms of understanding, development or progression from the previously held perceptions about science.

### **3.5 Research Instruments**

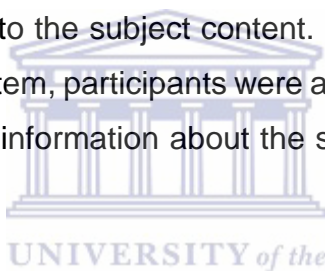
#### *3.5.1 Questionnaire*

Questionnaires are the most commonly used instruments for collecting information from programme participants when evaluating educational and extensional programmes (Colosi, 2006). This is also supported further by Taylor-Powell (1998) stating that questionnaires should be designed so that the questions gather essential

information. The *Pedagogical Learning for Scientific Literacy Questionnaire (PLSLQ)* was developed to gather information which was needed to identify the teachers' developmental needs pertaining to teaching and learning of physical science.

### **3.5.1.1 Development of the Pedagogical Learning for Scientific Literacy Questionnaire (PLSLQ)**

The questionnaire was designed to specifically elicit how physical science teachers interact with their students during lesson presentation. The questionnaire was designed in a manner that would not take too much time of the respondents but focused on determining the scope of NoS among teachers and students, hence questions were adapted from Views of Nature of Science (VNoS-B and VNoS-B) model. The PLSLQ was formulated so that the exercise of answering the questionnaire could generally be done by a science teacher as it contained science aspects in sections relating to the subject content. In the cases where teachers had just joined the education system, participants were allowed to work with other physical science teachers who have information about the students who would participate in the study.



The development PLSLQ was performed in several steps using methods and procedures consistent with best practices of developing a research instrument. The questionnaire was developed such that it could expose the adequacy of the teachers NoS, their awareness of their students' views of NoS and display the extent to which cooperative learning is used as an instructional method physical science teachers. The researcher sought to identify qualitative and quantitative measures that would be valid, practical, and useful for identifying the needs of the curriculum from physical science perspective.

The instrument had the following components: (a) a block of socio-demographic items like gender, current designation, academic experience etc., (b) a section on custodianship of student ideologies, (c) another section on student perspectives of NoS, (d) nature of science as a choice (NOSAC), (e) a section on curriculum principles and teacher support on teaching strategies, (f) and a separate section on the humanistic orientation. The questionnaire included a small number of scales (5), each containing a relatively small number of items. A Likert scale was used to obtain the

responses to the items. The Likert scale ranged from 1 to 5, with 1 for the most negative perception that represents almost never, 2 represents seldom, 3 represents sometimes, 4 represents often, and 5 for the most positive perception, which represents very often as adapted from *Computer-Assisted Learning Environment Questionnaire (CALEQ)* (Hartley & Treagust, 2014).

The PLSLQ was designed in such a way that it addressed both science content knowledge and instructional approach as a means of carrying out the context of the scientific content knowledge.

### **3.5.1.2 Development of Practicum Review Questionnaire (PRQ)**

The questionnaire was developed in such a way that the students were be able to answer it without assistance as the items were based on their experiences during the lesson presented in class. Demographic information was obtained and the student's questionnaire included a small number of scales (5), each containing a relatively small number of items. The scale's mean ranged from 1 to 5, with 1 for the most negative perception that represents not at all, 2 represents sometimes, 3 represents often, 4 represents generally, and 5 for the most positive perception, which represents almost always.

This questionnaire was developed and used in this research with an aim to review the practical part of the research, from the student's point of view. After the lesson was presented using CL to teach NoS, students were given a questionnaire in order to establish the effect the cooperative learning presented lesson had on their conceptual understanding and the impact it could have on the social interactions with their peers. This questionnaire served several purposes in the student sample:

- To collect information about the same questions from a bigger group of people
- To listen to diverse student views
- Detect trends in issues across diverse population.

The questionnaire was administered after the lesson was completed in a form of course evaluation. This exercise was viewed as more cost effective and time saving as the researcher was in the school site where the research was done. It also was hoped to get the information from the students while it was still fresh in students' minds regarding what had transpired in the few days when the lessons were presented.

### **3.6 CL intervention programme for physical science teachers**

The teacher support was intended to assist science teachers with cooperative learning and to understand the need for teaching nature of science to high school students and how the understanding of NoS could enhance the students' ability to retain what they have learnt and, in return, uphold scientific literacy. This programme was also in favour of the need to expedite confidence and teaching competencies to physical sciences teachers and to enhance the ability to deliver student-centred lessons and expert teaching founded on sound educational principles. The programme development was focused on supporting teachers with regard to specific aspects. The derivative for these aspects adhered to the current curriculum reforms and took into consideration the various dimensions of physical science curriculum in the Further Education and Training (FET):

1. Know, use, and interpret scientific explanation of the physical science content.
2. Generate and evaluate scientific evidence and explanations.
3. Understand the nature and development of scientific knowledge.
4. Participate productively in scientific practices and discourse.
5. Implement cooperative instructional strategy, linked to the broader knowledge and skills of the teachers, and the impact it would have on student performance.

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The intervention supported these curriculum dimensions by categorising and unpacking the teacher support aspects in order to show how they could be interpreted in the classroom context and how they could be achieved in every lesson. The detail of intervention programme is presented in Appendix B.

### **3.7 Data Analysis**

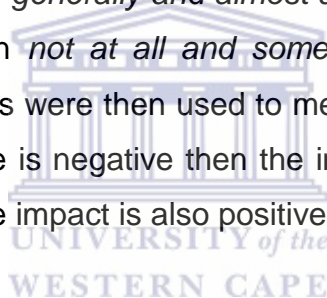
The researcher cleaned and scanned the data for errors manually. Video and audio data were scanned and colour coded for the purpose of categorizing them and finding themes and trends. Data that were collected by PLSLQ were transcribed in order to identify themes and later analyzed using excel spreadsheet and one theme was identified. Further probes to this theme culminated in four key themes. A video tape was used during for intervention activities and later transcribed into English, word for word and writing every detail for precise trends. In cases where the respondents used a language other than English, data were translated into English. Later data were triangulated and categorized into themes and further into key themes as there were

similarities. From videos there were two identified themes and five key themes. Figure 2 below outlines the data analysis strategy followed for video recording.



Figure 5: Data analysis strategy for videotaping.

The evaluation form given to teachers at the end of the intervention programme was analysed using the excel spreadsheet. Data collected using PRQ were also analysed using excel spreadsheet. Data were examined from a perception that students whose responses were rated *often, generally and almost always* were regarded as positive and those ranging between *not at all and sometimes* were viewed as negative responses. These responses were then used to measure the impact the lesson had on students. If the response is negative then the impact also is negative and if the response is positive then the impact is also positive.



### 3.8 Validity and Reliability

#### 3.8.1 Validity

The accuracy of data was maintained in order to have true results by focusing on the research questions and avoiding ambiguity in findings. The researcher used PLSLQ, Evaluation form, PRQ instruments as data sources so as to triangulate the results. The reliability of the questionnaires was tested prior to the actual research by piloting them with teachers who were not going to take part in the research. These member checks were asked to answer the questionnaires and highlight any forms of ambiguity. The researcher collected both instruments with responses. They were returned without any alterations, eliminations or inclusions. After analyzing data, the researcher concluded that these tools were valid as they could elicit how physical science teach in their respective classrooms.

### *3.8.2 Reliability*

For this study to be reliable, it should yield the same results even if it is performed with a different group of participants by another researcher. The researcher ensured this by piloting the instrument. Bulmer & Warwick (1993) raise concerns about reliability that for the instrument to be reliable it should yield the same results when the research is done by different people and under different conditions.

When the developed questionnaires were given to the research participants, they yielded the same results which could confirm the reliability of the instruments. This process was used to eliminate ambiguity and ensuring rigour.

### **3.9. Research Ethics**

Participants in the research were made aware that the research is for the researcher's studies and that they have a right to participate or decline to be part of the project. All participants were assured of professional conduct at all times, the obligation of the researcher to treat them with utmost respect, and the fact that the researcher would adhere to the principle of confidentiality and that all participants' names would remain anonymous. Permission was sought before conducting this study from the Eastern Cape DoE, physical science subject advisor, the principals of the affected schools, the Head of Department of the science department, physical science teachers who would be participants during the research and students from those identified schools. Furthermore, permission to observe the students in the classroom and to analyse their written work was sought from parents.

Since this research dealt with human beings, all the participants were requested to sign consent forms as assurance that the findings on the research would be used for research purposes. In that process the researcher ensured that participants understood the aims and procedures of the research process.

### **3.10 Conclusion**

The methodological strategy used to collect data was aimed at disclosing the understanding of cooperative learning by physical science teachers in this district and the extent to which they use this teaching strategy in their everyday lesson presentation. The instruments used were purposely selected in order to yield results that are valid and reliable. The findings from the collected data were discussed in the

following chapter with the full consciousness of the researcher of the ethical issues as the research was conducted under such protocol.





## CHAPTER 4

### FINDINGS

#### 4.1 Introduction

The detailed design of the methodology for this research, as expanded in the previous chapter, has enabled the development of this chapter. The steps mentioned in the methodological framework were followed as outlined in chapter three and resulted in the data detailed in this chapter. The findings in this chapter are presented according to the four research sub-questions that address the following main research question:

To what extent can cooperative learning (CL) enhance the understanding of nature of science (NoS) to advance the scientific literacy levels of secondary school physical science students?

#### 4.2 What was the teachers' knowledge of NoS and to what extent was NOS used as an instructional method for the understanding of science concepts?

The responses given by physical science teachers as per the questionnaire given to them were organised and set out in different categories. Each of these categories has registered data which is expanded as given in this chapter, taking note to detail and identifying trends. Of the fifteen teachers who were given a questionnaire, seven of them were properly filled in and returned. Findings of the study are tabled according to the themes from the questionnaire. When participants were invited to take part in this research, the researcher promised not to reveal the names of the participants, and it is for that reason that respondents in this questionnaire are referred to as Teacher A (T<sub>A</sub>), Teacher B (T<sub>B</sub>), Teacher C (T<sub>C</sub>), Teacher D (T<sub>D</sub>), Teacher E (T<sub>E</sub>), Teacher F (T<sub>F</sub>) and Teacher G (T<sub>G</sub>).

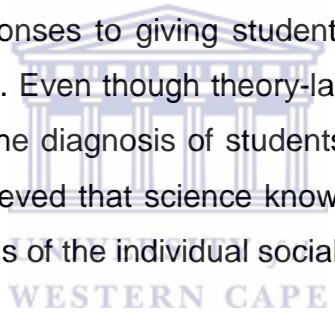
##### 4.2.1.1 Custody of student ideology by teachers

**Table 5: Teachers' Responses on custody of student ideology**

ITEMS/ PARTIC	T <sub>A</sub>	T <sub>B</sub>	T <sub>C</sub>	T <sub>D</sub>	T <sub>E</sub>	T <sub>F</sub>	T <sub>G</sub>	TOTAL	%
1	5	5	5	5	5	5	5	35	100
2	5	4	5	4	4	4	4	30	86
3	4	4	5	4	4	4	4	29	83
4	2	1	3	2	2	3	4	17	49

5	1	1	2	2	2	2	2	12	34
6	4	3	3	4	4	4	4	26	74
7	3	2	3	4	4	4	4	24	69
TOTAL	24	20	26	25	25	26	27	173	
AVERAGE	3,4	2,9	3,7	3,6	3,6	3,7	3,9		

In this category, the collected data were displayed so that they show individual participants with regard to all items asked for each item in the questionnaire. For item 1 all teachers attested to giving their students an opportunity to ask questions during their lesson presentation without fuss. Teachers seem to be 86% confident of their students' ability to respond to questions that are asked in class which are lesson related. With regard to assessment tools, 83% of the participants claimed that they use various assessment tools in order for them to validate learning. The individual intrinsic motivation and self-worth was rated to be 49% as perceived by teachers. However, participants' responses to giving students theory-laden based questions were revealed to be at 34%. Even though theory-laden based questions seemed to be at lower consideration, the diagnosis of students views of NoS was at 74% and 69% of the participants believed that science knowledge gained from their science classes is linked to the needs of the individual social life of a student.



These data were further represented by means of a chart so as to condense the above large amounts of information into an easy-to-understand format that clearly and effectively communicates important points. The graph shows individual responses of participants as per item in the questionnaire.

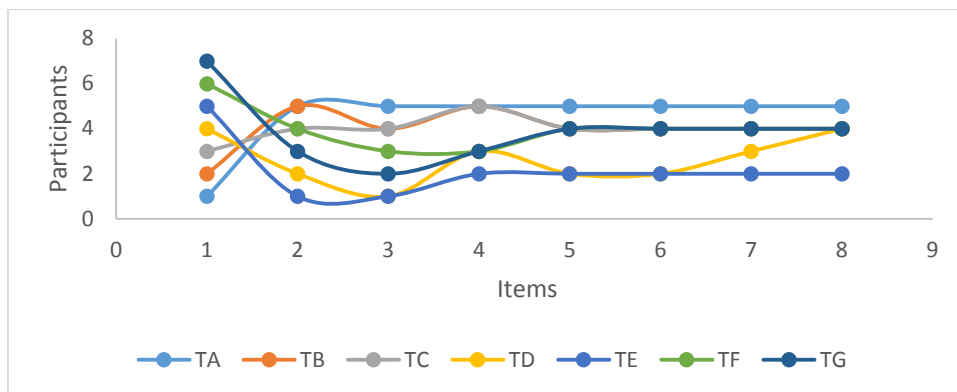


Figure 6: Individual teacher response on custody of student ideology.

#### 4.2.1.2 Student Perspectives of NoS

The table below demonstrates the teachers' opinions with regard to their students' perceptions of NoS.

**TABLE 6: Teachers' perceptions on student NoS**

PARTICIPANT / ITEM	1	2	3	4	5	6	7	8	9	10	TOTAL	AVERAGE
T <sub>A</sub>	4	4	1	1	1	5	4	3	5	1	29	2,9
T <sub>B</sub>	4	5	2	1	1	5	1	3	5	1	28	2,8
T <sub>C</sub>	2	4	4	1	3	4	2	4	5	3	32	3,2
T <sub>D</sub>	4	5	2	1	3	5	3	3	4	1	31	3,1
T <sub>E</sub>	1	5	2	1	2	4	3	3	3	2	26	2,6
T <sub>F</sub>	4	5	3	1	4	4	1	3	4	1	30	3,0
T <sub>G</sub>	4	5	2	1	4	4	2	5	5	2	34	3,4
TOTAL	23	33	16	7	18	31	16	24	31	11	210	
%	66	94	46	20	51	89	46	69	89	31		

Data were presented according to what each teacher participant perceived students' views of NoS. According to what data revealed, 66% of participants attest to the view that their students view science as a practical subject capable of empirical testing and that was substantiated by data. 94% of participants shared the idea that their students have an understanding that scientific knowledge is developed through understanding nature which contributes to a network of laws, theories and concepts. Furthermore, participants' responses showed that only 46% of their students showed enthusiasm towards physical science investigations.

Contrast was made between students' performance working in a group and those working as individuals. The results showed that only 20% of the teachers leaned towards the perception that students performed better when working in cooperative groups. The socio-cultural context of the majority of students emphasizing and encouraging learning of certain scientific related skills while minimizing others, was rated at 51%. Contrary to that, participants could attest to an idea that 89% of their students hold a perception that science is procedural more than creative. The collected data also revealed that 46% of the teachers hold a view that their students believe that existing scientific knowledge remained relevant only when there was non-refute on such. 69% of the teachers think that their students adhered to the notion that scientists are particularly objective.

When it came to an issue of students' cautious attitude towards the use of indigenous knowledge when explaining scientific phenomena, data revealed that practice to be at 89%, and 31% of the students being able to design their own problem solving plan which could lead to uncovering the scientific truths or supporting existing findings. This information was also simplified by the use of a graph for quick understanding.

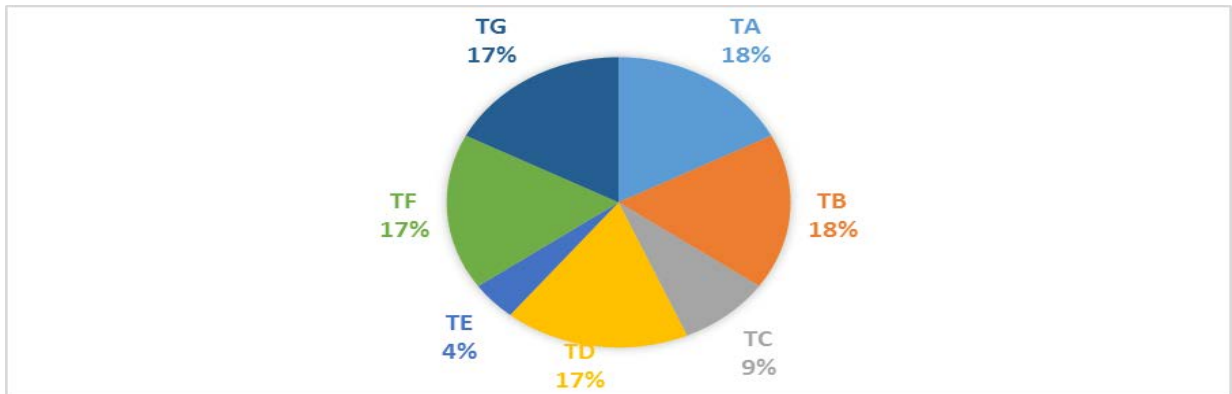


Figure: 7: Teachers' opinions on Students' perceptions of NoS.

#### 4.2.1.3 Nature of Science as a Choice (NoSAC)

Table 7 below shows how the participants responded to the items in a questionnaire.

**TABLE 7: TEACHERS' PERCEPTIONS ON NOSAC**

ITEMS	T <sub>A</sub>	T <sub>B</sub>	T <sub>C</sub>	T <sub>D</sub>	T <sub>E</sub>	T <sub>F</sub>	T <sub>G</sub>	TOTAL
1	5	5	5	5	5	5	5	35
2	4	3	3	2	3	3	4	22
3	1	1	1	1	2	4	3	13
4	1	2	1	1	2	1	2	10
5	2	2	2	2	3	2	1	14
6	1	2	1	1	1	1	1	8
TOTAL	14	15	13	12	16	16	16	102
%	47	50	43	40	53	53	53	49
AVERAGE	2,3	2,5	2,2	2,0	2,7	2,7	2,7	17,0

The data as tabled above, in relation to item 1, show that all the respondents strongly agree with the notion that scientific knowledge relies heavily, but not entirely, on observations, experimental evidence, rational arguments, and inference. With regard to the argument presented in item 2 that observations are theory-laden, 63 % of the respondents supported that notion. The collected data have also shown for item 3 that the majority of teachers are not in a position to deal with the tentativeness of science due to new developments in research, without them doubting the authenticity of science as a way of explaining natural phenomena, as 37% in the table reveals for this item. The responses for Item 4 from the questionnaire as the data reveal, sits at

29% for the knowledge in relation to the laws and theories serving different roles in science and that theories do not become laws even with additional evidence.

For item 5 of the questionnaire, 40% of the respondents think that they are in a position to motivate and enable students to use their social and historical culture to influence their scientific thoughts. In the last item in this category, on the issue of whether the teachers are able to inspire students to an extent that they develop creativity, the use of imagination and the urge to gather evidence for further scientific development and growth, the results show that 29% of teachers are able to achieve this aspect. These data were further represented in a graph to reveal the views of each respondent on this particular theme, comparing the responses as per individual respondent.

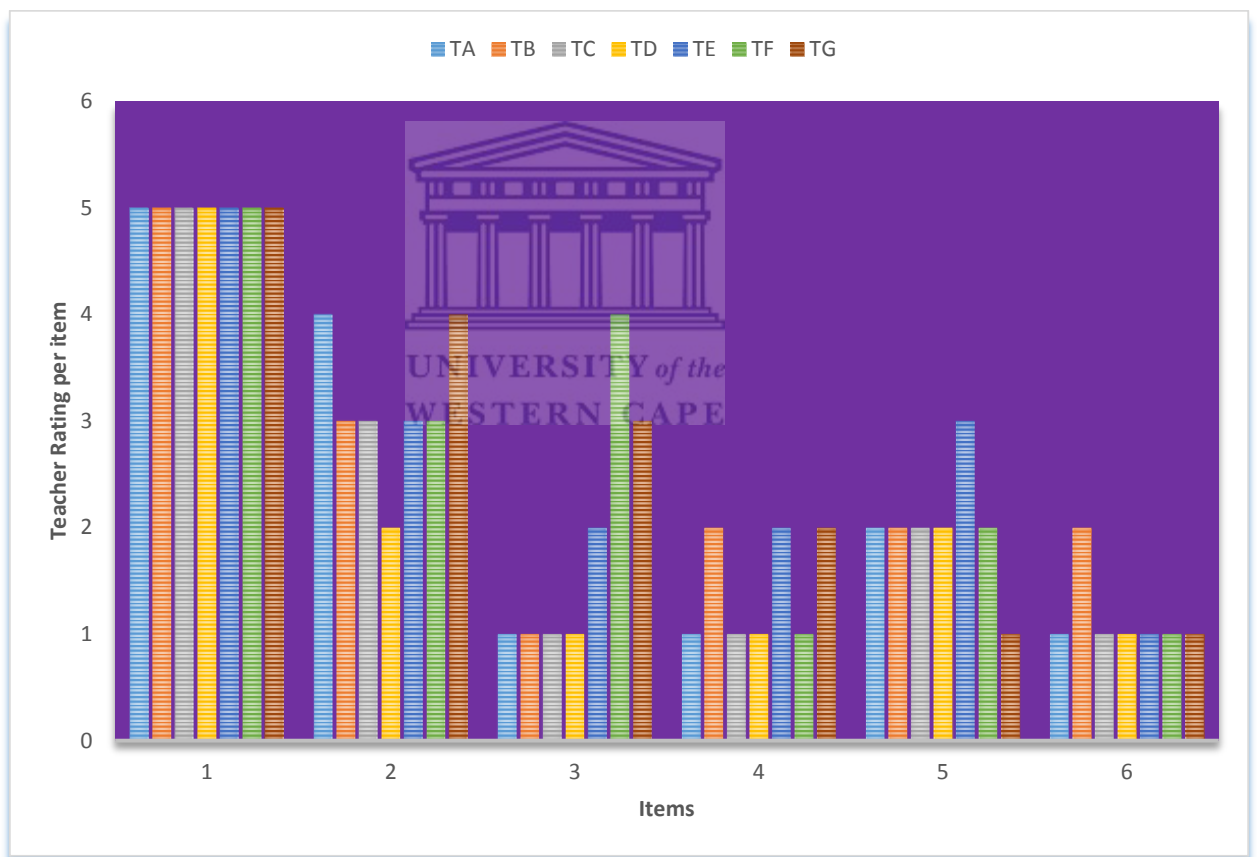


Figure 8: Graph showing the teachers' understanding about NoS and its everyday use in a classroom situation.

The graph shows the scale mean range for the different items where it shows the similarities in understanding of the individual items from the questionnaire. From the graph, the majority of the respondents have a view that is below average for items 3, 4, 5 and 6.

#### 4.2.1.4 Curriculum Principles

Table 8 below reveals the responses by individual teachers from the questionnaire on curriculum principles

**TABLE 8: TEACHERS' UNDERSTANDING ABOUT CURRICULUM PRINCIPLES**

ITEMS	T <sub>A</sub>	T <sub>B</sub>	T <sub>C</sub>	T <sub>D</sub>	T <sub>E</sub>	T <sub>F</sub>	T <sub>G</sub>	TOTAL
1	2	4	4	4	2	3	2	21
2	4	4	4	4	4	4	4	28
3	3	2	2	3	3	1	1	15
4	1	1	3	2	1	1	1	10
5	2	1	1	2	4	2	3	15
TOTAL	12	12	14	15	14	11	11	89
%	48	48	56	60	56	44	44	51
AVERAGE	2.4	2.4	2.8	3	2.8	2.2	2.2	17.8

The understanding of the curriculum expectations by the teachers is crucial for the best delivery of the curriculum to students and also a tool to measure whether or not students achieve the envisaged outcomes. In this category, five questions were asked and teachers' responses were recorded in the table as shown above. The results reveal that 60% of the teachers are in a position to unpack the aims of the curriculum and 80% of them identify with the view that the current implementation encourages the teaching of NoS. However, the data show that the teachers seem to disagree with the notion of the departmental effort in assisting with the understanding and delivering on the aims of the curriculum, hence 42% of teachers are happy with the support they are getting. With regard to item 4, 29% of teachers attest to the knowledge of tools used by the education department to develop and assess the understanding of the teaching strategies promoting scientific literacy. On the question of forums and clubs, 42% of the teachers attest to the interactions with regard to discussions about teaching strategies for improving student performance. The data collected were also translated by means of a graph as shown in figure 13 below.

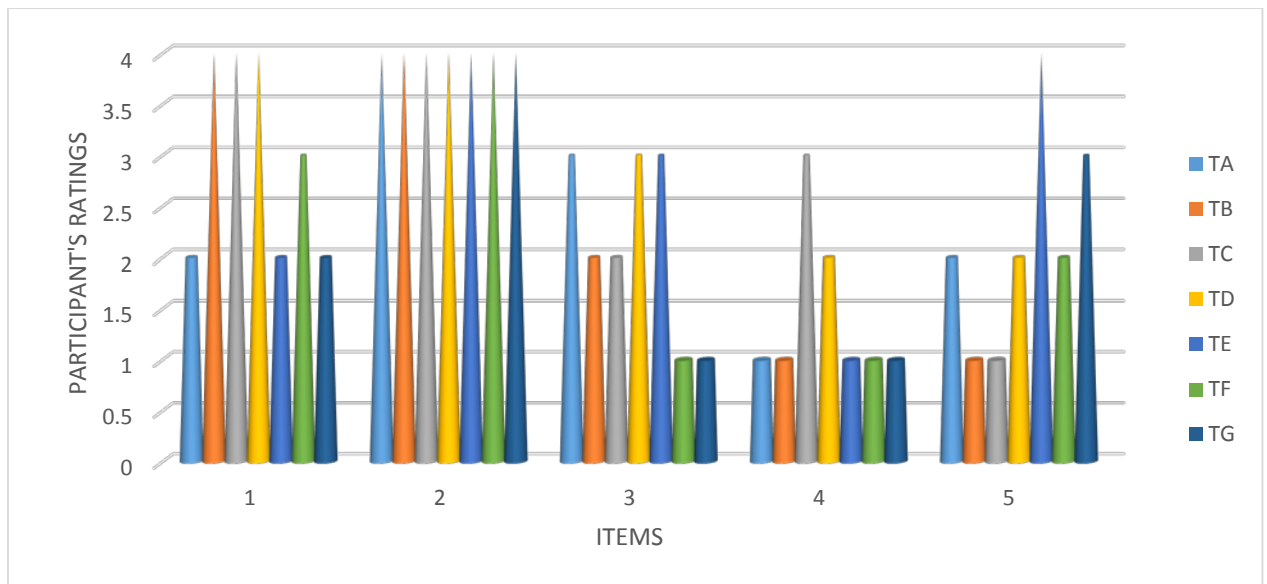


Figure 9: Teacher understanding of curriculum principles

#### 4.2.1.5 Humanistic Orientation

In this section of the teachers were very lengthy on their responses and were answering using their own perceptions and perhaps experience. The researcher categorised data into themes for each questions in this section of the questionnaire

Question 1 had five categories and these are: (a) Always during the lesson (ALWAYS). (b) Mostly during the lesson (MOSTLY). (c) Partly during the lesson (PARTLY). (d) Rarely during the lesson (RARELY). (e) Never during the lesson (NEVER). The second question had three themes and are: (a) changing the instructional method (METHOD). (b) Motivate (MOTIVATE). (c) Inform parent (INFORM). (d) Interview students (INTERVIEWS). Themes for question 3 are: (a) Allow students to work in groups (GROUPS). (b) Introducing student in class discussions (DISCUSSIONS). (c) Assigning group projects (PROJECTS). Question 4 identified the themes which are: (a) Identifying safety measures (IDENTIFY DANGERS). (b) Teach safety methods (TEACH METHODS). (c) Supervise students during practical work (SUPERVISE). themes identified in question 5 are: (a) Assign roles to students in groups (ROLES). (b) Monitoring discussions per group (MONITORING). (c) Bridging knowledge gaps (KNOWLEDGE GAPS). Identified themes for question 6 are: (a) Involves social issue (SOCIAL). (b) Embraces indigenous knowledge (INDIGENOUS KNOWLEDGE). (c) Encourages human involvement (HUMAN INVOLVEMENT). Question 7 themes are: (a) Team work (TEAM WORK). (b) Giving sense of responsibility (RESPONSIBILITY). (c) Hold students accountable for their work

(ACCOUNTABILITY). The last question themes are: (a) Familiarize students with science laws and theories (LAWS AND THEORIES). (b) Give more practical work (PRACTICAL WORK).

The collected data based on the identified themes were presented as shown in Table 9.

**TABLE 9: TEACHERS PERCEPTIONS ON CLASSROOM RELATIONS**

C A T E G O R Y / P A R T I C I P A N T	A L W A Y S	M O S T O F T H E M	P A R T L Y	R A R E L Y	N E V E R	M O S T O F T H E M	I N T E R V I E W S	I N F O R M S	G R O U P S	D I S C U S S I O N S	P R O J E C T S	I D E N T I F Y	T E A C H E R S	S U P E R V I S E	R O L E S	M O N I T O R I N G	K N O W L E D G E	S O C I A L	I N D I D E N T I F Y	H U M A N	I N V O L V E M E N T	T E A M	R E S P O N S I B I L I T Y	A C C O U N T A B I L I T Y	L A W S A N D T H E O R I E S	P R A C T I C A L W O R K
TA				X		X			X			X			X				X		X				X	
TB	X					X			X				X			X			X		X					X
TC			X			X			X				X			X			X		X					X
TD		X				X			X				X			X			X		X					X
TE				X			X		X			X				X			X		X					X
TF	X					X			X				X		X				X		X					X
TG		X				X			X				X			X			X					X		X

The collected data assisted the researcher to draw trends on how teachers conduct their everyday lessons in their respective classrooms. The trends are that teachers mainly allow their students to use their local knowledge in class. When students do not show interest in science lessons, two out of seven teachers claim that they change their instructional methods and three teachers say that they motivate students. Two other teachers, respectively confirmed that they interview students and inform parents.

When teachers' skills on developing team work among their students were examined, three of them said that they encourage students to work in groups and two others showed that they introduce student in class discussions. The remaining two teachers' skill was to give the students group projects. The majority of teachers claim that they supervise their students so that they practise safety precautions and at the same time explore and learn scientific concepts as they conduct experiments. Two teachers



stated that they teach the safety precautions and then allow students to explore and learn. Two other teachers said that they identify dangers for the students when conducting the experiment.

One teacher claimed to be assigning roles to students as they work in cooperative groups whereas four others demonstrated that they move around groups in order to monitor the students. The remaining two teachers stated that they go around groups listen to what students say and intervene by explaining concepts and bridge the knowledge gaps. The majority of teachers were saying that science is a social enterprise as it involves human explanations and deductions and the other two teachers viewed it as one that has to involve the students' indigenous knowledge and social abilities for gathering knowledge respectively.

Four teachers claimed that they would encourage students to work in groups in order to build team work and the other four opted for promoting individual work, though their reasons were different but interlinked. Two of them said that they preferred assigning individual work because they wanted students to be responsible for their learning and the others advocated for accountability. Only two trends could be identified for this question and five of the teachers said that they would teach students laws and existing theories and two claimed that they would give more practical work.

#### **4.3. How was the Cooperative Learning programme implemented to enhance teachers' understanding of NoS?**

The intervention in the form of a mentoring programme was administered after collecting data on demographic information of the participants. The programme had to balance the information gathered from the questionnaire with the aims of the study in order to draft the key elements of the programme. When the intervention was conducted, the following themes were marked as key elements:

##### *4.3.1 Developing adequate conceptions of nature of science*

Teachers were given an activity exploring their understanding about nature of science. They were grouped into three formal cooperative learning groups and were given a case study based activity exploring their understanding about nature of science.

Group A participants comprised three teachers, two males and one female, and the males are referred to T<sub>A</sub> and T<sub>B</sub> respectively and female T<sub>C</sub>. Group B comprised four teachers, three females and one male; females were referred to T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> respectively and male T<sub>4</sub>, and Group C had three females and were named T<sub>X</sub>, T<sub>Y</sub> and T<sub>Z</sub>.

*Recent research studies on science education acknowledge that scientific knowledge relies heavily, but not entirely, on observations, experimental evidence and rational arguments. It is also evident that science changes with new developments in research, and students have to be aware of this fact and still not doubt the authenticity of science as a way of explaining natural phenomena. Design a physical science lesson from which the above can be proved to be true. Give a brief explanation with examples based on the current curriculum in order to support this notion.*

Group A participants had to decide on the topic to be presented for this particular exercise. It took the group sometime to come to a conclusion as T<sub>C</sub> was claiming that she was interested in knowing how the other teachers were teaching Newton's second law of motion. T<sub>C</sub> said that her students are not performing well in this topic whereas she had always thought that it was the easiest to understand. T<sub>B</sub> requested the other members to choose the topic from the grade 9 syllabus as he claimed that his school would be taking in grade 9 students the following year. T<sub>A</sub> was the quiet one and the group ultimately agreed on Newton's second law of motion. The group then started brainstorming the lesson plan that would feature the aspects of the case study.

T<sub>B</sub> advised the team to have an experiment for the first part of the case study but was defeated by the second part.

*As much as I agree with the second statement of the case study, but I don't know how we can show it in a lesson. [T<sub>B</sub>]*

*Maybe if we can start by revising Newton's first law, then give them a definition of the second law; then it could cover the second section. [T<sub>C</sub>]*

T<sub>A</sub> jumped in and proposed

*It would be better if we started with what we know because the time for the presentation will come when we have nothing to present [T<sub>A</sub>]*

They then started to work on their project. All group members were actively involved in the lesson drafting and T<sub>C</sub> was nominated to do the presentation. Their lesson introduction was based on forms of forces which are contact forces and non-contact forces and gave examples of each type of force. They also gave a definition of Newton's second law of motion and derived the mathematical relationship i.e.  $F \propto a$ , indicating that the object could be resting on an inclined plane. T<sub>C</sub> demonstrated how objects can slide up or down the inclined slope and identified forces that act on the object when the slope is frictionless and when it is a rough slope.

Group B, which comprised four members, decided on taking a topic in grade 12 as they all happened to be teaching grades at this level. T<sub>3</sub> suggested that they plan a lesson on Rate and Extent of Reaction and the rest of the group agreed. The outline of a lesson had the introduction on the Collision Theory whereby they stated that particle collision led to chemical reactions and the rate of reaction can be increased by the increase in the number of possible effective collisions.

*In other words, the more often we can make atoms collide, the faster the reaction will take place. [T<sub>3</sub>]*

The presentation also delved into the factors that Influence the rate of reaction and explained how each factor contributed to the rate of reaction. T<sub>3</sub> further explained that the rate of reactions can be measured by observing how reactants disappear or products appear, change colour, change phases and mass.

*If we had apparatus we would demonstrate in an experiment to show the speed (rate) of a reaction under different conditions. [T<sub>3</sub>]*

Group C had three members and one of them had been a life sciences teacher for a period of eight years but was currently teaching three life science groups and one grade 10 physical science group for the first time. During the time when they were choosing the topic, the other two members of the group took that into consideration

and had to choose from the grade 10 syllabus. They chose the periodic table as was advised by T<sub>γ</sub> as he claimed that it would fit the scenario given.

*Let's take the periodic table since we will be able to talk about how elements were discovered. This can also assist us with the discussions on the developments since the first element was discovered. [T<sub>γ</sub>]*

They defined the periodic table, stating that it shows the arrangement of elements according to their atomic weights. These elements discoveries were due to the works of ancient scientists, and as the elements were discovered so as the periodic table changed, as a result there are one hundred and eight elements found in the periodic table.

*We believe that other elements could still be discovered and form part of the periodic table. [T<sub>x</sub>]*

This ordering shows periodic trends, such as elements with similar chemical characteristics in the same column called groups. Six groups have generally accepted names as well as numbers: for example, group 7 elements are the halogens; and the group after 7 is called group zero. They explained the reason why there was no group 8 using the electron distribution in an atom. CAPE

*Atoms of a group zero elements have eight electrons in their outer shell hence they are called inert gases. [T<sub>x</sub>]*

The group differentiated between columns and rows.

*Rows of the table are called periods. The periodic table can be used to derive relationships between the properties of the elements, and predict the properties of new elements yet to be discovered or synthesized and provides a useful framework for analyzing chemical behaviour, and is widely used in chemistry and other sciences. [T<sub>x</sub>]*

From the aspects of NoS that this research focused on, teacher participants were asked questions which they had to answer as individuals and then were later discussed by the entire group. The participants in this section are named in the same

manner as they were named in their cooperative groups. Questions were based on the tentativeness, empirical nature, theory-laden nature, observation and inference, the roles of and distinction between scientific laws and theories. This was done in order to answer the questions that students might have on why they have to learn science and also why teachers teach science. Secondly, it was aimed at answering a question of how scientists know and interpret scientific phenomena. Participants responded to different questions and the responses were transcribed.

*Scientists do not have direct access to most natural phenomena. Explain how you think they gather information for the explanations they have with regard to natural phenomena.*

T<sub>A</sub> responded by saying that most scientists happened to discover aspects of nature by accident and then they later try to perform experiments in order for them to have convincing arguments about particular phenomena which he assumed could be through trial and error.

*Since there can be many scientific methods, some could have been discovered by trials aiming at getting the same results. [T<sub>A</sub>]*

WESTERN CAPE

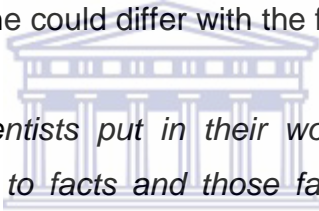
T<sub>4</sub>, T<sub>X</sub>, and T<sub>Y</sub> were in support of the fact that observation played an important role as some of the natural phenomena can be literally observed by naked eyes whereas others need equipment due to limitations of the eyes. Having said that, T<sub>Y</sub> went further and claimed that scientists, at times, make speculations about things and are unable to prove them, but surprisingly after sometime, evidence is found and that evidence is recognised. The other five teachers shared a different view to the issue as they made mention of the use of theories.

*In some instances, scientists compared the natural aspects to other things they can reach and examine, and if they have similarities, they then come up with a theory that suits both aspects. Just like in the case of the field lines, they can only be observed in magnets but not in electrical charges. [T<sub>1</sub>]*

T<sub>1</sub>, T<sub>B</sub> T<sub>C</sub> T<sub>Z</sub> and T<sub>3</sub> shared the same view as they said that the use of theories is the best way of clarifying things that cannot be observed, either by naked eye or equipment.

*Laws and theories serve different roles in science and hence theories do not become laws even with additional evidence; how would you explain that?*

Five participants shared the same view as the given statement as they argued that the oldest theories like Big Bang theory and kinetic theory are still called theory even though they were developed many years ago. The reason for this, according to them, was that theory is based on assumptions which involve observation and inference whereas laws can be viewed as descriptive statements of relationships among observable phenomena. The other two participants had different views. T<sub>2</sub> stated that laws were derived from a series of investigations until it was conclusive throughout the science scope and no one could differ with the findings.



*The effort that scientists put in their work investigating science related phenomenon result to facts and those facts are referred to as laws and theories would differ probably because there could still be some developments that could arise from further investigations. [T<sub>2</sub>]*

T<sub>A</sub> views laws like the other participants except that he stresses much on evidence and that the phenomenon behaves in that same manner under any conditions. He differs with them with the theory view.

*Without evidence then the concept around that phenomenon is called a theory. [T<sub>A</sub>]*

*As much as I would want to believe this statement in terms of theories not becoming laws but I think they serve the same purpose which is explaining science. [T<sub>X</sub>]*

T<sub>2</sub> somehow agreed with T<sub>X</sub> but wanted her to explain what significance does the naming have if they are both used to explain scientific phenomena.

*Why can't they be called laws or theories? [T<sub>2</sub>]*

*The fact that laws can only be derived from direct observation and analysis they therefore differ from theories as theories also have a lot to do with people's assumptions and reference from existing knowledge. [T<sub>2</sub>]*

*Sometimes the knowledge you say exists is not accepted by everyone which is why one person who is unhappy with that body of knowledge, would make sure that he or she proves that knowledge incorrect. Please allow me to say that there is no concrete and ever standing of scientific knowledge cause if new evidence comes, then the previous knowledge is forgotten. [T<sub>1</sub>]*

The debate became the centre of everyone's attention until I intervened by saying that we should tie this discussion with the last question of the activity. Of course I intended for the group to understand the tentativeness of scientific knowledge as alluded to by T<sub>1</sub>. From the creativity point of view, it appeared that all the participants agreed therefore that without curiosity and effort of the human race, there would be no development in science; hence they all agreed that laws can't be theories and vice-versa but can complement one another.

The logo of the University of the Western Cape, featuring a classical building facade with columns and a pediment, with the text 'UNIVERSITY of the WESTERN CAPE' below it.

*In your experience as a physical science teacher would you argue that scientific knowledge is theory-laden?*

The distinction between scientific theories and laws continued to be part of this deliberation as four of the participants posited that scientific theory and laws cannot be forgotten when teaching science. They reiterated that scientific knowledge is dependent on scientific theories and laws. Contrary to this, the other two participants claimed that scientific knowledge is based on experiments and evidence the experiments yield to since they claimed that not all scientific situations required people's background knowledge and their perceptions.

*Every conclusion that scientists make depends on their experience and the gained knowledge. If you test the pH of water, and the reading is seven, how will you know that water is neutral if you don't have the background knowledge about the meaning of the readings on the scale? No matter how*

*much we want science to be this body of knowledge which does not have flaws, we can't avoid it, yes it is theory laden. [T<sub>γ</sub>]*

The other participants claimed that if they were to dispute the statement then it would mean that they are going against what they had agreed upon earlier in the discussion, hence they agreed with T<sub>γ</sub>.

*Research shows that the number of emerging scientists is not growing the way it is expected, looking at the number of challenges the world is facing. In order to remedy this situation, science teachers are urged to motivate students into taking part in science growth and development. Explain how you would encourage students to use their social and historical culture to influence their scientific thoughts while you advocate for science as a human enterprise*

All participants talked about how they can motivate students to choose science as a career in order to contribute positively in the development of science and the improvement of socio-economic factors.

*There is a fewer number of students who graduate science related courses and that leads to fewer number of science teachers in our communities and students are without science teachers in rural areas. [T<sub>A</sub>]*

Having said that, the participants feel that the most upheld beliefs are those of the western culture and very little is done to develop indigenous knowledge.

*I don't believe that the government is doing enough to recruit and fund students who want to pursue science as their career. Let alone the current university curriculum has nothing to do with how traditional healers' way of mixing medicine. [T<sub>4</sub>]*

*Scientists are creative and often resort to imagination and speculation; explain how you would explain that kind of behaviour to your students.*

Three participants still believed in the students' exposure to various scientific environments like laboratories so that they can see how experiments are conducted; that could help them see and not use or entirely depend on their imagination.



However, the other four participants held a view that creativity is a result of imagination and imagination is a result of curiosity, therefore students should be challenged with difficult science concepts so that they can use their imagination and become creative even if such exercises are not for examination purposes.

*The students' background cannot be eliminated from the manner in which students reason, how do you know that students are capable of thinking scientifically because giving them difficult and intriguing tasks can only make them believe that they are in a wrong field, and can even decide to drop out of school. Even if we can try, our students are still dependent on the telling method or else you will find yourself talking alone. [T<sub>1</sub>]*

The other two participants were amazed at how rich science was and how little they have done in terms of allowing students to understand how science can make them realise themselves and become scientists in the true sense.

*Perhaps if we could start by showing them how science has changed over the years, maybe they can be encouraged to start by following their instincts if they have questions about some of the things said to be holding some truth. But of course, be encouraged to reason scientifically and use local science and knowledge. [T<sub>3</sub>]*

#### *4.3.2 Instructional Practices and Teachers' Perceptions*

For the purpose of capturing these data and abiding by the ethics code, the participants were named as T<sub>A</sub>, T<sub>B</sub>, T<sub>C</sub>, T<sub>D</sub>, T<sub>E</sub>, T<sub>F</sub>, T<sub>G</sub>, T<sub>H</sub>, T<sub>I</sub> and T<sub>J</sub>. The evaluation form had three categories i.e. low, medium and high. For the medium rated views, the scores are between two and three and for high rated views the score is between four and five. Ratings two and four meant that the participant had wished to experience more of that aspect either within the range of medium or high rates. The colour code for low was red, for medium with further expectations was blue and medium without any further expectations was green. The colour code for high with expectations was black and the one without further expectations was yellow. The responses from the

evaluation form were colour coded into the themes and analyzed using thick description.

The first theme was the teacher's perception on the use of cooperative learning in the physical science lesson presentation. The scores were recorded and the average for this theme was recorded as shown in figures 14, 15 and 16.

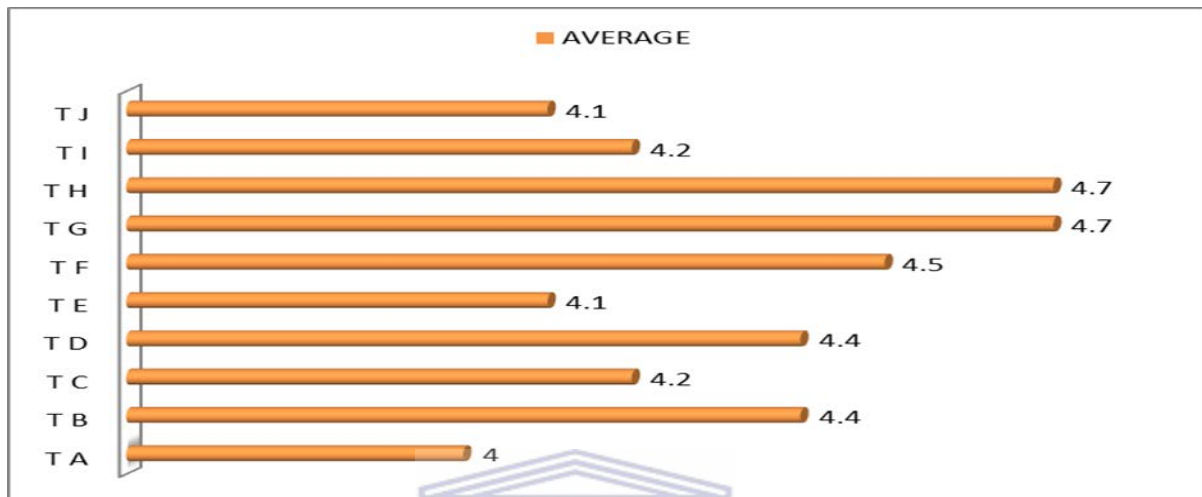


Figure 10: Teachers' perceptions on the use of cooperative learning

The graph reflects that the perceptions of teachers towards the use of cooperative learning when teaching physical science, after the workshop, rated high. Three teachers i.e. teacher F, G and H were more confident than the other teachers as their average rate was 4.5 and above. The other teachers rated below 4.5 which is still a high level though they slightly differ. Teacher A rated herself at level 4 followed by teachers E and J with the same level. Teachers C and I also were at the same rate of 4.2 and teachers B and D at 4.4 level.

The second theme was on the teacher's' perceptions on the benefits of teaching NoS to their physical science students and this is what the results have shown.

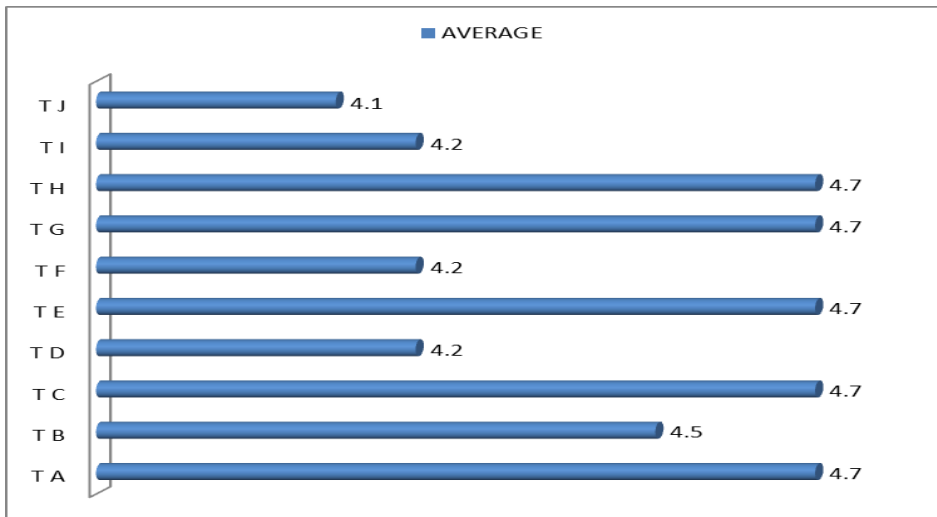


Figure 11: Teachers' perceptions on benefits related to teaching NoS.

50 % of the teachers rated at an average of 4.7 which shows a higher level of rating on the perceptions about how teaching NoS will benefit them as teachers as well as their students. With regard to the ability to use nature of science to diagnose students' areas of difficulty, teachers also showed a higher level of confidence. 10 % of the teachers rated at level 4.5 and the remaining 40% rated themselves at 4.2 and 4.1 respectively.

The third theme was on the teachers' perceptions on their content knowledge and students' benefits, and this is what the results have shown.

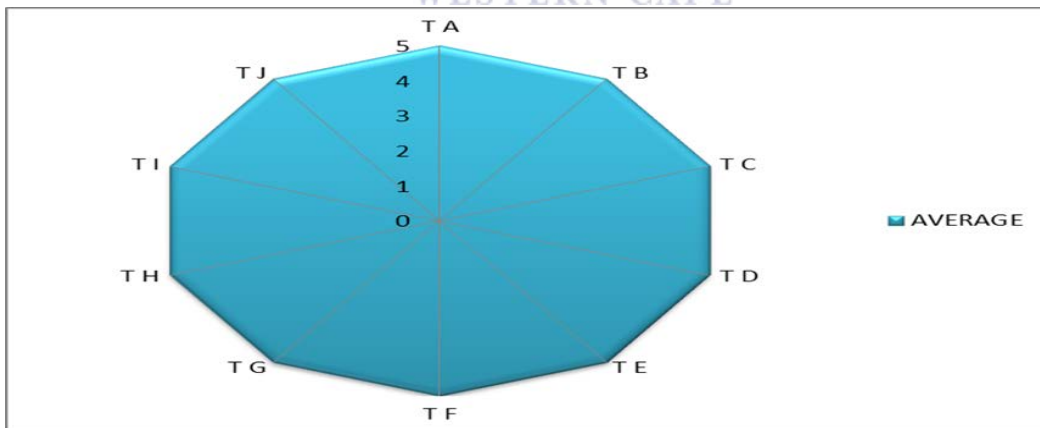


Figure 12: Teachers' perceptions on their content knowledge and students' benefits

All the teachers rated themselves at the high level. 100% of teachers rated at high level without any question or doubt. All of them shared the same sentiment that their content knowledge would completely benefit their students.

#### **4.4 How did teachers implement cooperative learning when teaching NoS in their physical sciences classes after the intervention programme?**

Teacher A and F volunteered with their grade eleven and grade ten classes respectively for practical implementation of teaching NoS using cooperative learning. We had two lesson presentations, where teacher A was the main teacher for the grade 11 lesson and the co-teacher in the grade 10 lesson. Teacher F was the main teacher in the grade 10 lesson and the co-teacher in the grade 11 lesson. The checklist was used to assess both teachers but only when they were main teachers in the lesson.

##### **Lesson 1**

Teacher A's lesson was on The Electric Field and the lesson plan is attached as Appendix D. The students in this class were already seated in groups. The teacher introduced the co-teacher and the mentor as teachers who were in their class to gather good teaching practices and also share some with her. She urged the students to participate in the lesson as they always do. The teacher assigned group roles where there was a group leader and the scribe. She mentioned that these roles will rotate until everyone had a fair share of the role.

The lesson was a follow up question as the teacher asked questions based on the development science she had given them in the previous lesson. The students raised their hands and answered as individuals. The teacher tested the student's understanding of Field as a follow up lesson and further stressed that students have to remember that a Field is an abstract concept.

*You must always remember that a field is an abstract concept used to describe how particular forces act upon certain particles or bodies in a region.*

[TA]

Teacher A clarified her statement by referring the students to the concept of gravity where she asked students to work in groups and represent forces acting on an object resting on the table and the falling objects. She then asked students to raise their diagrams so that she could see them. She later worked on how to arrive at the correct diagram and she called the diagram a vector diagram. The teacher showed the students that the downward force due to gravity is the gravitational field, which can be shown and described as a vector.

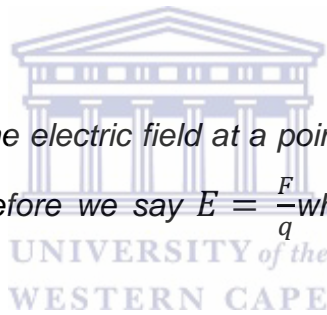
*Similarly, electric fields exist around electric charges and can exert forces on any other electric charges in their presence. Charges that are far enough away from the field source may be regarded to be at infinity if the force acting on them by the field is negligible. [TA]*

The teacher explained how Michael Faraday arrived at the idea of an electric field that forms around a charged object and extends outwards from the charge into space.

*Faraday claims that when a second charge is placed near the first charge, that charge will experience the force due to the electric field. [TA].*

In her demonstration she showed students how the potential exists between any two points in a field such that work must be done to move a point charge from one point to the other.

*That is what we call the electric field at a point, the force experienced per unit positive charge. Therefore we say  $E = \frac{F}{q}$  whereby both  $F$  and  $E$  are vector quantities. [TA]*



*Mr F is now going to show you what happens if more than one charge contributes to the field. [TA]*

*Before we can proceed it is important for us to understand the difference between the charge that experiences the force in an electric field and the one that creates the electric field. [TF]*

Students were given a task to work in groups and write the electric field when a point charge is put in the electric field of two charges- for spherical objects with different charges and in two parallel plates. From the four groups of eight and two groups of seven students, the following were their responses.

The groups presented their work on the direction of the electric field at a point and three groups i.e. G1, G3 and G 7 shared the same idea.

1.  $E_1 \longleftarrow$        $E_2 \longleftarrow$
2.  $E_1 \longrightarrow$        $E_2 \longrightarrow$
3.  $E_1 \longrightarrow$        $E_2 \longrightarrow$  [G7]

G1, G3 and G7 shared the same view about the electric field at a point and argued that field is a vector so if its direction is from positive to negative then the point charge will move from P to Q. the point charge between  $Q_1$  and  $Q_2$  will accelerate towards  $Q_2$  as it experiences a force of repulsion from  $Q_1$  and as the field moves away from  $Q_2$ . Point  $p$  will accelerate towards  $Q_A$  due to attraction force between  $Q_A$  and positive point charge and because of the direction of the field lines.

Groups 2 and 4 share the same view as group 3 but differed on the field at point  $p$  between  $Q_1$  and  $Q_2$ . They claim that the field is pointing to the left due to  $Q_1$  and to the right due to  $Q_2$  pointing to the right.

1.  $E_1 \longrightarrow$        $E_2 \longrightarrow$
2.  $E_1 \longleftarrow$        $E_2 \longrightarrow$
3.  $E_1 \longleftarrow$        $E_2 \longleftarrow$  [G4]

Group 5 presented their conclusions and put forward their claims as to how they arrived at conclusions about the field at a point. This group had the same argument, that  $p$  will accelerate towards  $Q$  due to the force of attraction. For the second question they said that  $p$  will be attracted to  $Q_1$  and repelled by  $Q_2$ . In the case of the field next to  $Q_A$  they said that  $p$  was repelled by  $Q_B$  and attracted by  $Q_A$ .

1.  $E_1 \longrightarrow$        $E_2 \longrightarrow$
2.  $E_1 \longrightarrow$        $E_2 \longleftarrow$
3.  $E_1 \longrightarrow$        $E_2 \longrightarrow$  [G6]

The teacher drew the students' attention to the point charge as dependent on the direction of field and the direction can be determined by the field line. He then told the students that when the point is placed in the field between two charges, the field is the combination of the two fields taking into consideration that the field is a vector quantity.

## Lesson 2

Teacher F presented a lesson to his grade 10 class. His lesson was on gravitational potential energy and is provided in this study as Appendix E. The teacher asked students to write down the definition of energy and then discuss it with the person

next to them. After peer discussions, the groups then shared their views with the whole class. The first group to answer was called G1.

*Energy is the capacity to work. [G1]*

The teacher asked the rest of the groups if they agreed with G1 and all the groups agreed with this statement but one group had something else to say. That group was then called group 2.

*Energy is the source of power. [G2]*

The teacher then told students that energy is the capacity to do work. The teacher neither explained why the second answer was not acceptable nor justified correctness of the first answer. Students were then grouped into six cooperative groups of seven students and one group of eight students. The teacher gave numbers to each student and told the students to sit according to those allocated numbers. From the groups, he asked students to assign the three roles i.e. group leader, scribe and time keeper. The teacher explained to students the role of each student in a group. The teacher later gave the students a worksheet based on energy sources and types and told them to work together; he also allocated five minutes for brainstorming, discussion and writing. Groups were later given three minutes to present to the class their answers.

From the new seating arrangements groups were named G1, G2, G3, G4, G5, G6, G7; G7 was the only group with eight students.

*Sources of energy are the sun, stoves and fires. The types of energy are potential energy, kinetic energy heat and light energy. [G3]*

*Sources are the sun, fuel, generators and electricity and energy types are heat and light energy, electrical energy, potential energy and kinetic energy. [G4]*

The teacher asked students if there were any additions.

*Solar energy. [G6]*

*The sources and the types of energy that you mentioned are correct except that you did not mention the mechanical energy which I want us to closely look at today. Is there anyone who understands what mechanical energy is? [TF]*

Seemingly students did not know it and just kept quiet.

*Mechanical energy is the total amount of potential energy plus kinetic energy in a system. The formula for calculating potential energy plus the formula for calculating kinetic energy gives us mechanical energy e.g.  $E_{mech} = E_p + E_k$ , where  $E_p = mgh$  and  $E_k = \frac{1}{2}mv^2$ . [TF]*

It was then Teacher A's chance to elaborate further in the lesson.

*If I may explain how we get to this point as Mr F said. [TA].*

Teacher A explained the difference between potential energy and the gravitational potential energy. He explained the concept of gravity and gravitational acceleration by using Galileo's experiment of the Leaning Tower of Pisa. He also emphasized that energy cannot be created or destroyed but can be transferred from one form to another. He took the students back to the forms of energy they mentioned and asked them about the energy conversions.

*Some of you mentioned the solar energy, which we get from the sun, but that solar energy we use it at our home to charge our phones and play TV. That means solar energy is converted to electrical energy. The same happens with gravitational potential energy, as the objects falls down due to the force of gravity, this energy is converted to kinetic energy because now the object is in motion. [TA]*

She went further to explain how change in energy affects mechanical energy. The gravitational energy at the height where the object is dropped will be equal to kinetic energy at the lowest point of the height. Mr F will later explain the conditions for these conversions Teacher A then gave time for teacher F to continue with the lesson.



Teacher F gave students a calculation to work on in their small groups as shown in the lesson plan.

#### 4.5 What were students' perceptions of the CL class implemented by their teacher?

The Practicum Review Questionnaire that was given to a grade eleven class of forty six students at the end of the lesson.

##### Group A

The questionnaire was categorised into three themes and yielded results as detailed in figures 13, 14 and 15.

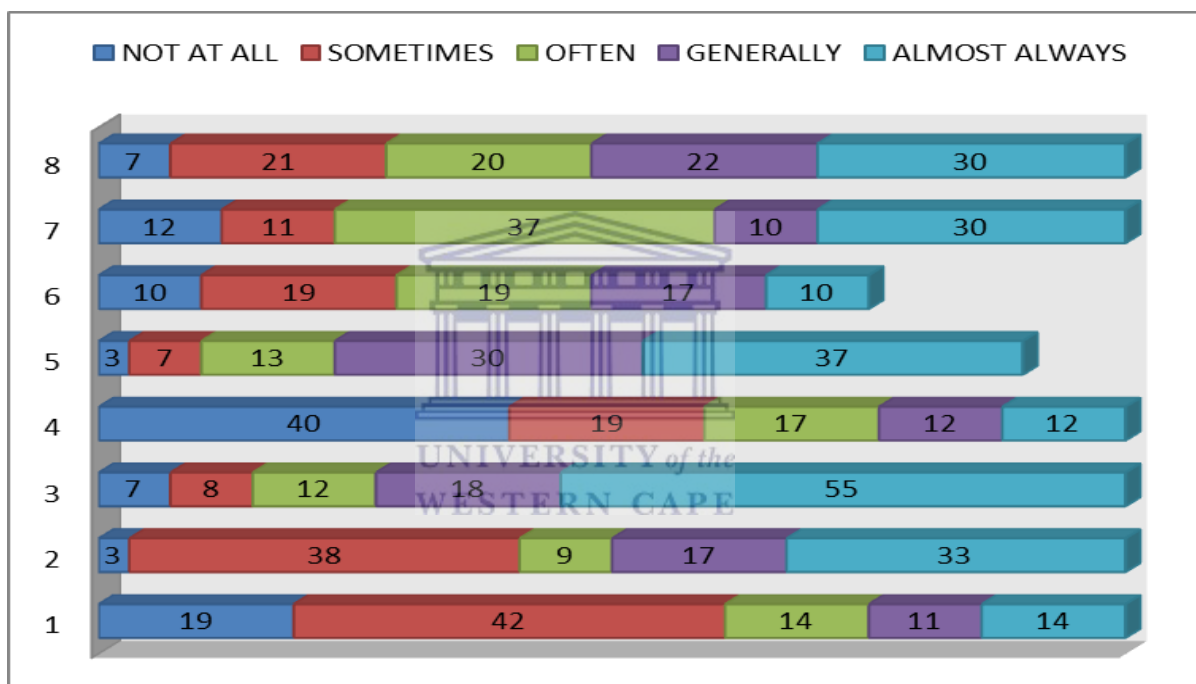


Figure 13: Perceptions of learning in cooperative learning groups after the lesson

The graph shows that 80% of students said that they enjoyed helping other group members with what they are good at understanding. Data also show that 80% of students were eager to contribute towards the tasks assigned by their teacher in class. Evidence also shows that 77% of class A experienced that learning material is easier to understand when working with other students and 72% also view nature of science as the way of knowing. Furthermore, data reveal that 61% of the students were intolerant with the other members of a small group. For item 2, 41% of the students did not agree that working in a group helped them to overcome their shyness. 59% student participants claim that their groups were not organized.

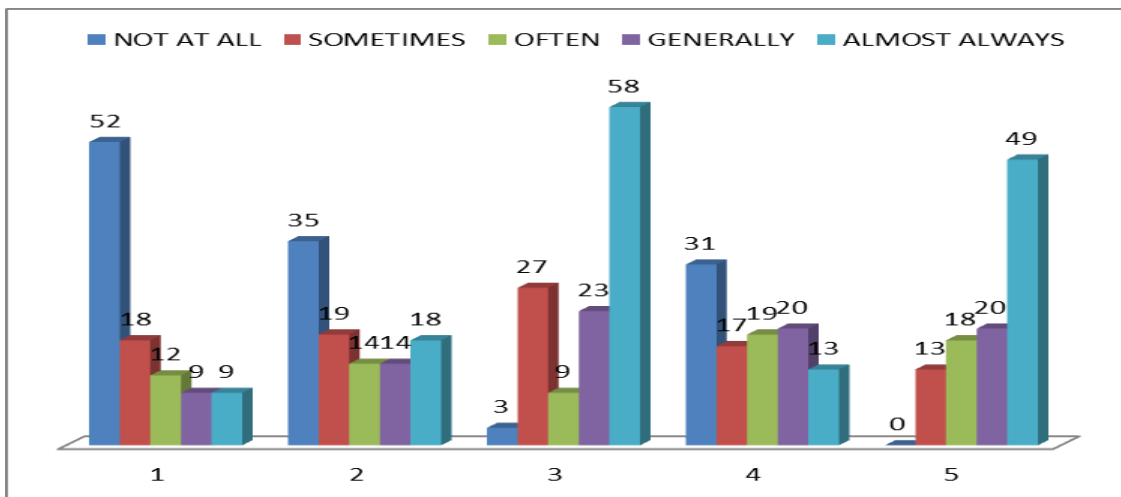


Figure 14: Students' Perceptions on cognitive development

The graph shows the students' responses which enabled the analysis with regard to their perceptions on cognitive development. 52% of the respondents demonstrated that the knowledge on the development of science with regard to the lesson on electric field was not relevant at all. Only a smaller percentage recognized that the knowledge was of importance. 18% felt that it was for some reason beneficial, 12% claimed that they often used it during the lesson and 9% agreed that they mainly needed to use the knowledge for understanding scientific concepts.

Data reveals that 35% of the respondents say that their teacher almost always failed to identify their areas of difficulty whereas 14% of them say that they often realized it and another 14% generally felt that their problems were identified. 19% of students attested that they sometimes felt that their areas of difficulty were identified and attended to and 18% of them claimed that they were almost always identified and addressed.

According to collected data, 58% respondents attested to the understanding of how scientists arrived at conclusions addressed and 3% of them claimed that they did not understand at all. 27% of the respondents' understanding was sometimes witnessed and 23% of them said that such understanding was mainly revealed. 9% percent of students showed that this understanding was often realized in the lesson.

31% of the respondents did not agree that the lesson has taught them that science changes with new developments and observations but only 13% of them said they

gained that kind of knowledge almost always. 17%, 19% and 20% of respondents ranged from sometimes, often and general with regard to understanding this tentative aspect of nature of science respectively.

Data demonstrated 49% of respondents' claims that they understood the concept of the lessons presented. 20%, 18% and 13% of students perceived the lesson as generally, often and sometimes, gained the concept understanding respectively. All respondents attested to the concept understanding.

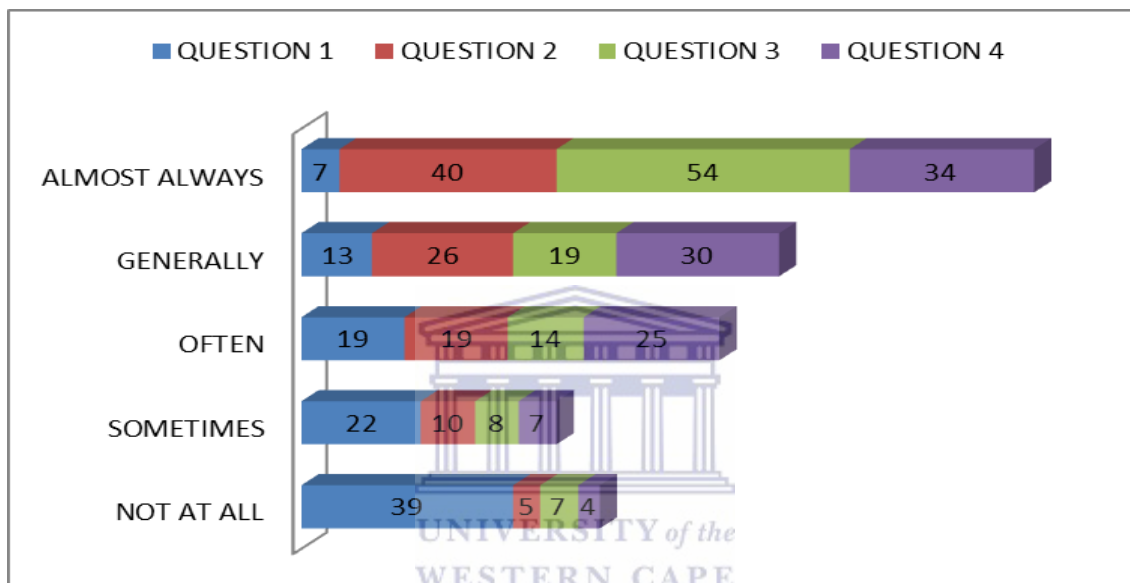


Figure 15: Students' Perceptions on Social and Personal Development

Data displayed that 39% of respondents were still carrying an idea that there is one-way method of arriving at scientific conclusions. 22% claimed that they sometimes held the notion that there is no one-way method and 13% say they often learnt that from the lesson. 13% of students claimed that they generally learnt this from the lesson and 7% say that they almost completely learnt that.

5% of students did not agree to the notion that scientific laws and theories are derived from human curiosity and 10% of them say that they sometimes agree with this notion. 19% stated that they often agree and 26% mainly agree. 40% of the students almost always agreed with this aspect of nature of science.

54% of the students revealed that they were encouraged to do further individual research about science. 19% claimed that they were mainly enthusiastic to do further

research and 14%, 8% and 7% respectively felt they would often, sometimes and not at all, conduct individual physical science research.

A smaller percentage of students did not agree with the idea that science can be learnt from social contexts hence data shows 4% of them saying not at all, 7% sometimes would and 25% claim that they often agree. 30% claim that they mainly agree and 34% is mostly confident.

### Group B

The same Practicum Review Questionnaire that was given to class A was also given to class B, a group of fifty grade ten students, and the results are detailed in figures 16, 17 and 18.

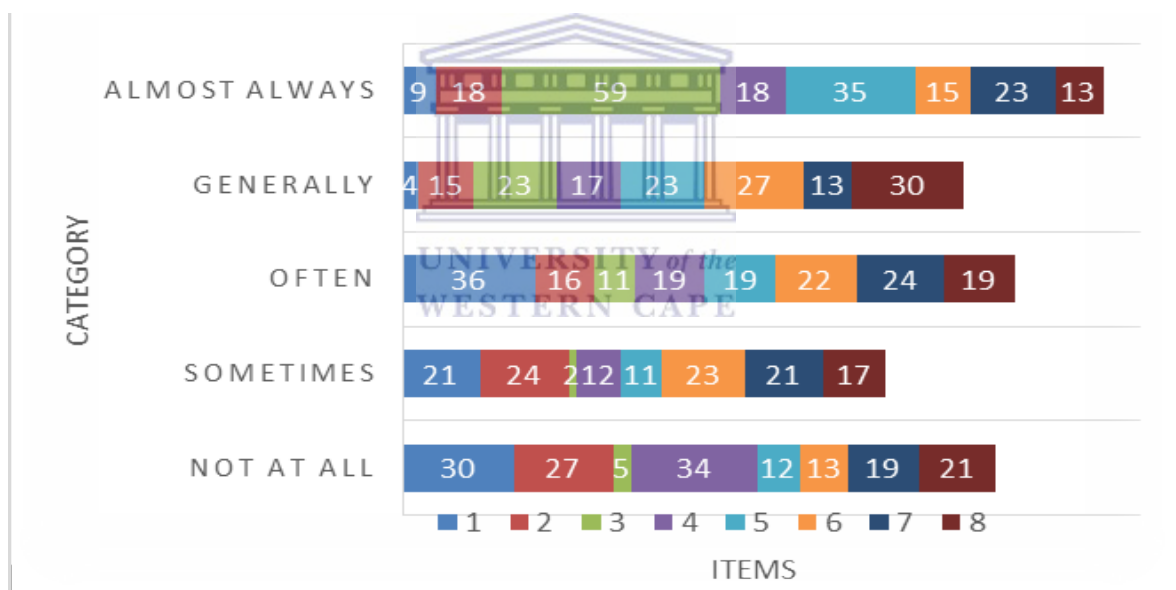


Figure 16: Perceptions of learning in cooperative learning groups

Students' perceptions for this group of student participants were analysed exactly the same way as class A. Data shows that 51% of students did not become more patient while being part of a small group and that working in a group did not help them to overcome their shyness. Further evidence showed that 93% of participants agreed that they enjoyed helping in the groups with their strengths. With relation to the group organisation, 54% claimed that their groups were organised compared to the rest of the class. Data also shows that 53% of participants were keen to contribute to the assignments. 77% believe that members in their groups benefited from their

contributions to learn the material they were supposed to learn and 60% claim that learning material was easier to understand when working with other students. How students viewed nature of science was shown in this study whereby 62% of them view it as the way of knowing.



Figure 17: Students' Perceptions on cognitive development

The grade 10 student responses gathered data showing that 30% did not see the need for their teacher to present the development of science for this particular lesson. 23% percent revealed that sometimes there was relevance and 16% of them said that it was often relevant. 19% of the respondents attested to the general relevance and only 12% viewed it as mostly relevant.

In this category, data demonstrated that 22% of students felt that their areas of difficulty were not addressed at all whereas 15% stated that sometimes it was addressed during the lesson presentation. 20% of respondents said that it was often addressed and 27% said that it was mainly attended to. 16% showed that their areas of difficulty was almost always identified and attended to.

The knowledge of how scientists arrived at the scientific conclusions was often understood by 33% of the respondents, and 20% and 16% was generally and almost always understood respectively as data shows. 19% of them claimed that they sometimes understood and 12% said that they did not understand at all.

15% of the students said that they almost always agree that science changes with new observations. The other 20% showed that they generally agree the notion. 31% of them

claimed that it was often the case whilst 19% said that it sometimes was the case with science. 12% said that they did not agree at all.

21% of the respondents claimed that they almost always understand how scientists arrive at scientific conclusions for the particular lesson presented to them. 20% said that they generally understand but 20% say they often understand. Those that did not understand at all were 15% of the population and another 15% said that they sometimes understand.

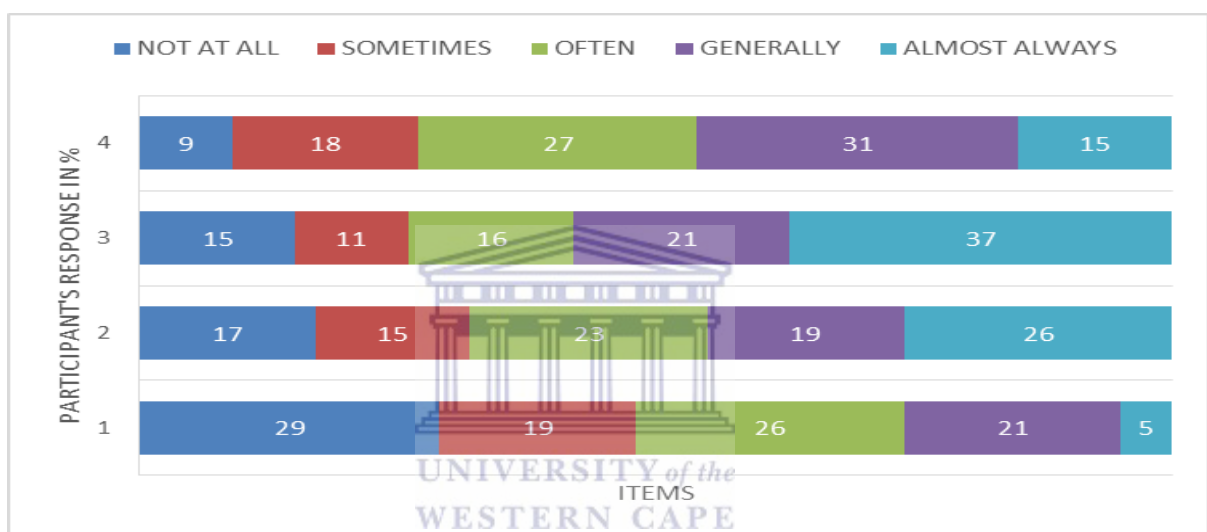


Figure 18: Students' Perceptions on Social and Personal Development

Data displayed that 29% of respondents were still holding the idea that there is a one-way method of arriving at scientific conclusions. 19% claimed that they sometimes held the notion that there is no one-way method and 26% say they often learnt that from the lesson. 21% of students claimed that they generally learnt this from the lesson and 5% says that they almost completely learnt that.

17% of students did not agree to the notion that scientific laws and theories are derived from human curiosity and 15% of them say that they sometimes agree. 23% stated that they often agree and 19% mainly agrees. 26% of the students almost always agreed with this aspect of nature of science.

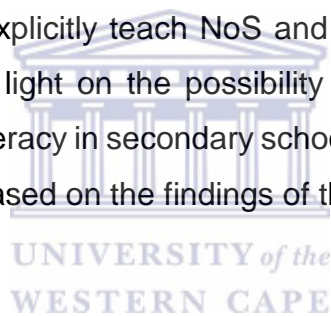
37% of the students revealed that they were encouraged to do further individual research about science. 21% claimed that they were mainly enthusiastic to do further

research and 16%, 11% and 15% respectively felt they would often, sometimes and not at all conduct individual physical science research.

A smaller percentage of students did not agree that *I learnt that science can be learnt from social contexts* hence data shows 9% of them saying not at all, 18% sometimes would and 27% claim that they often agree. 31% claim that they mainly agree and 15% is mostly confident.

#### **4.6 Conclusion**

The findings in this study reveal that some teachers' NoS is not adequate which is one reason they could not teach nature of science explicitly. For those teachers with adequate NoS, they still did not explicitly teach its aspects due to finding no reason to do so. The content knowledge was the only reason they were still teaching. The positive discovery in this study was regarding the students' benefits when the lessons are structured in order to explicitly teach NoS and the use of cooperative learning. This experience also shed light on the possibility of NoS instructional method for advancement of scientific literacy in secondary school students. The following chapter makes recommendations based on the findings of the study.



## CHAPTER 5

### DISCUSSIONS

#### 5.1 Introduction

The purpose of this chapter is to interpret and elaborate on the exposed data and explain the trends, detail the implications of the findings, and make suggestions for future research. The results are explained in order to answer the questions posed in the introduction and how they support the deductions. The deductions are also viewed against the existing knowledge on the topic.

#### 5.2 NoS knowledge and its use as an instructional method

From the section of a questionnaire examining the understanding of Nos, five trends were identified and rating were categorized as follows. Entirely (90% – 100%), Mostly (75% - 89%), Partly (60% - 74%) and No relevance (0% – 39%). Examining these trends, taped on the important aspects of NoS. The imperative aspects of NoS as advocated by Lederman and many other researchers with the likes of Jonson and Jonson are the understanding of science being theory laden, tentative, scientists ability to formulate theories from validated set of reasoning and the understanding of the fact that under no circumstances can theories be turned to laws. Teachers demonstrated that they entirely concur with the NoS notion in some of its aspects. Both science being tentative and theories remaining theories were rated below 39 % considering the identified trends. The interpretation to this is that teachers do not think that these aspects are of any importance in the teaching and learning of science.

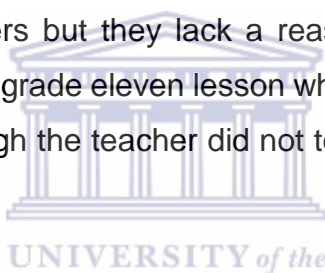
In addition to this, data shows that 50% of the participants rate the importance and practicality of teaching NoS to their students between seldom and almost never, hence they do not even consider its inclusion during lesson preparations and presentations.

Another significant finding was that more than 50% of teachers declared that their lessons seldom engage creativity and imagination. The fact that this was revealed by data collected and that there is a lack of platforms where students use their social and historical culture to advance science understanding coincides with the attested levels of challenging students' conceptual opinions. This therefor is evident that teachers are not aware of the students' scientific misconceptions.



During the interactions in the workshop it was evident that 20% of participants have acceptable PCK though they have different views about different aspects of NoS. That is shown by the argument put forward by T<sub>Z</sub> and T<sub>1</sub> in the discussions about the distinction between theories and laws. 80% of the novice teachers who participated in the intervention programme lack the understanding of NoS and how it can be used as a way of teaching. During the intervention workshop, T<sub>B</sub> attested to the lack of understanding as to how students can be taught the tentative part of science.

From the lessons presented, there is evidence that very little was taught on the views of NoS. This showed that teachers have difficulty with explicit teaching of NoS to students and the concept of content knowledge seems to be conflicted with NoS. The lessons are more focused on concept gains. Further, the views of NoS are distanced from lesson presentations. The inability to justify the correctness of the concept points to an urgent need to develop PCK. However, there is evidence of acceptable views of NoS in other novice teachers but they lack a reason to teach NoS. The aspect of inference was evident in the grade eleven lesson where students had to determine the electric field at a point, though the teacher did not teach the students using analogies within their social context.



### **5.3 Application of CL to enhance the understanding of NoS.**

During the intervention programme, teachers had an opportunity to interact with one another in small cooperative groups. In their group interactions they were challenged into demonstrating their knowledge about Nos views. The debate over laws turning to theories shows that the participants have unacceptable views of NoS. In this discussion, it is proven that teachers are able to argue and bring forward their views about science. Collaboration in a group led to teachers' misconceptions being exposed. These misconceptions were then diverted using the power of cooperative learning. The opportunity to interact, exchange ideas and correct misconceptions is an indication that CL application encouraged teachers to rethink their understanding of NoS. It also was evident that CL enhanced the understanding of NoS in the process of engaging science theories and laws.

When teachers were responding to *PLSLQ* in section C, it showed that their students were performing better when they worked alone than in groups. According to the teachers' views, students seem to be unable to work individually. It can therefore be

deduced that students need to be encouraged to work in groups so as to advance peer expertise and create platforms for learning science through social and historic culture. When teachers' skills on developing team work among their students were examined, three of them said that they encourage students to work in groups and two others showed that they introduce student in class discussions and other two teachers attested to giving the students group projects. In a classroom situation where students are given such opportunities to interact with one another, social interdependence is encouraged and students get to be creative and gain knowledge from such interactions. Of course, this can only be achieved when conditions for interactions are satisfied and each students understands roles in a groups. Surprisingly so, students who have been exposed to lesson teaching NoS explicitly, they would not experience any barrier to performance whether in a group or as an individual.

Teachers also highlighted that their students cannot strike a balance between science taught at school and the attainable skills which could enable them to design a problem solving plan such that they contribute meaningfully to science development. Another aspect probed by *PLSLQ* was how teachers reflect on their students' justification of scientific phenomena and their conceptual opinion. To a certain extent, teachers are in a position to know the students; views and would somehow be able to address student's misconceptions or affirm their understanding. If teachers were to probe further on the students conceptual phenomena, they would also tap on the students' indigenous knowledge. When students' indigenous knowledge is appreciated and made useful to improve scientific understanding, students will be encouraged to reason scientifically using their local context. By so doing, teachers would be endorsing the aims of the current curriculum as stated in the CAPS document.

Reflecting on the findings of the study and claims made by Shulman (1986), Ramnarian and Schuster (2014) it is evident that teachers successful science teaching demands knowledge of how to transfer content knowledge using appropriate teaching approaches for specific topics and particular groups of learners. It therefore is of importance to acquaint teachers with different instructional strategies hence cooperative learning was key to enhance the teaching of NoS in this study.

#### **5.4 Scientific literacy advancement from teaching NoS using CL**

The results suggest that teachers view the use of cooperative learning as a useful teaching strategy they can employ in their classes when teaching physical science. This was revealed by efforts made by teachers during the lesson presentations. Even though teachers did not interrogate students' reasoning, they still guided them on how to interpret content knowledge. The skills gained and eagerness to teach using cooperative learning also gave the students a platform to engage with and help other students in the groups with what they know and are good at. Looking at how each teacher views teaching of NoS, it then shows that teachers understand its benefits and how these can affect the students' scientific literacy.

In the grade eleven lesson, the teacher showed how science has developed and also that new investigations can still be conducted and new evidence uncovered that can influence scientific knowledge. In this lesson the teacher presented evidence of the view of science as tentative, theory laden and laid emphasis on the role of observations and inference. This then shows the skill of explicit teaching of NoS.

During the lessons, both teachers could not present the scientific concepts using the students' Indigenous Knowledge Systems (ISK) and analogy.

The concepts remained abstract though they could have been easily explained using the students' background knowledge.

#### **5.5 Students' views on CL-NoS instructional method during a physical science lesson**

Grade eleven students welcomed the CL approach to their lesson. This was shown by the responses they gave in the PRQ. The results showed that students had enjoyed the lesson as they attested to the pleasure they had gained by helping other group members during the lesson presentation. Another interesting finding in this study was that the majority of students felt at ease working with their peers, hence they say that the study material became easy to understand when they worked in small groups. The study also shows that these groups of students were pleased to have been part of this lesson as evidence shows that the positive response in this category is far above the average.

Even when the instructional method was administered to a totally different group of students, in terms of age and standard of education, the same results were found. The second group of students also alluded to the fact that they mainly viewed Nature of Science as the way of knowing, as more than half of the class agreed. The importance of resourced students with scientific knowledge was not overstated as both groups of students showed enthusiasm towards assisting other students with the knowledge they possessed. Adding to this was the fact which emerged, the students' ability to understand the learning material much more easily when they were working with their peers in cooperative groups.

Another interesting finding in this study was that in the case of the teachers' ability to provide teaching strategies to explain the scientific ideas, the teachers favoured restating their own understanding with their teaching approach. One reason for this is that teachers present lessons whilst racing against time to finish the day's topic without taking time to develop the students' reasoning ability. Another reason for this is that novice teachers tend to view teaching as a telling exercise and not a skill of presenting the content for effective learning. This was observed when the teacher asked students if they understood mechanical energy. The teacher did not probe students' cognitive skills but just told them the answer. In some cases, participant teachers did attempt to relate the concepts to be explained in ways that pupils could understand, for example, through the use of analogies.

An additional significant finding is that, of those who gave acceptable scientific answers, the teacher responses indicated that they were aware of pupils' likely misconceptions. However, in their responses, teachers omitted to consider the pupils' likely misconceptions in their teaching suggestions and preferred to restate their own understandings as a strategy.

## **5.6 Conclusion**

The use of cooperative learning when teaching scientific concepts empowered students as they attested to working better in a group than alone. The understanding of the benefits of teaching NoS to physical science students enhanced certain scientific skills like observation, inference and scientific reasoning which could be learnt depending on the socio-cultural context of the student. The findings revealed that the current state of science is more logical than creative. Some teachers believe that their

students only accepted the relevance of fact rather than theory. Dealing with student's identified misconceptions was a challenge as teachers were unable to address them. The belief that teachers had about their students that scientists are objective observers anticipated that these students are less likely to pursue science as a career of choice.



## CHAPTER 6

# CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Introduction

This chapter contains conclusions, recommendations and limitations to the study. It was established from the literature that the explicit teaching of NoS has not been a priority by either practitioners or the education authorities in many countries. It has been evident that even in South Africa, there is no particular focus on this aspect.

The study originated from the evidence and recognition that student performance in physical science at matriculation level, particularly in historically disadvantaged public secondary schools of South Africa, is deteriorating yearly and has resulted in massive shortages in the scientific workforce in all sectors. Sitting with such a shortage of scientifically advanced workforce and practitioners, teachers are gradually exiting the education system. The DoE has not been turning a blind eye to this as there are programmes in place trying to mitigate the situation. These programmes range from organized winter schools, spring school to camps. From these endeavours by the DoE in the district where the research was done physical science results do not seem to be recognizably improving. This research therefore taps into various causalities in this crisis. These range from expecting students to learn without presenting lessons that activate their internal mental processes, teachers' intention to transfer knowledge to students, inadequate PCK conceptions, less focus on assessing the students' current level of cognitive strengths and weaknesses in order to apply appropriate teaching approaches to inadequate teacher developmental support for teachers.

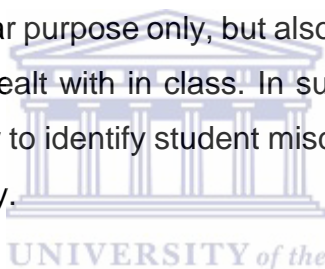
Literature established that the use of various instructional methods could improve the current status. It is against this background that the study was undertaken to develop teachers in the use of cooperative learning to enhance teaching of NoS for scientific literacy advancement in secondary school physical science students.

This section presents the conclusions obtained from the study. It summarizes major research findings as they appear in data analysis and presentation of both questionnaires and the evaluation sheet. The purpose of the use of these instruments was to uncover whether or not the developed use of cooperative learning could enhance teaching of Nature of Science to secondary students in order to improve

scientific literacy and produce improved results. Furthermore, the study relates the research findings to previous studies obtained from the literature review and justifications of this study.

It is important to highlight that some of the research findings in this study replicate results of previous studies done elsewhere in other countries. However it is also crucial to realize that this study extends those findings to the Bizana District in the Eastern Cape.

The results of this study suggest that developing science novice teachers' PCK at pre-service level would be beneficial for them, especially for those who lacked content knowledge. Nevertheless, given adequate teaching experience and continuous guidance from teacher development forums and team teaching, teachers will position their lesson presentations to teach NoS explicitly. They will not only position the lesson presentation for this particular purpose only, but also to understand the students' views about the learning aspect dealt with in class. In such forums teachers might as well develop one another on how to identify student misconceptions and derive conceptual change and scientific literacy.



After the intervention, teachers realized the benefit of explicit teaching of NoS. The lesson presentations show an effort to introduce the teaching of NoS. Such development, however, may not occur automatically, hence social interdependence is paramount for both students and teachers.

The instruments used in this research, they assisted the researcher to the students' enthusiasm at becoming sources of scientific knowledge and how they would benefit from this instructional method.

## **6.2 Recommendations**

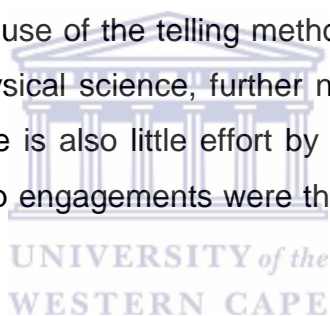
South African curriculum reform design promotes teaching of NoS, but there is no evidence of putting this important aspect of science education into action, especially in the previously disadvantaged communities. The departmental officials, teachers and all education stakeholders should endeavour in the explicit teaching of NoS in schools. This will encourage South African students to think scientifically and be able to derive scientific conclusions. The Department of Education should work closely with newly

employed teachers and identify areas of development and NOS orientation in order to facilitate scientific literacy.

Teachers' PCK should be developed in order for them to diagnose and eliminate students' misconceptions. This will then positively affect the students' scientific literacy. Cooperative learning related theories, particularly social interdependence, should be encouraged as it will provide an opportunity for students to eliminate their misconceptions. The shared goals would be accomplished through the contribution and influence of the actions of others; hence the teachers' contributions need to be aligned with NoS in order for students to advance in scientific literacy.

### **6.3 Implications**

The fact that teachers have limited understanding of NOS means that students are not in a position to reason scientifically. The teachers' PCK needs to be developed so that teachers can relinquish the use of the telling method. The application of cooperative learning when teaching physical science, further needs to be reinforced in order to maximise its benefits. There is also little effort by the teachers to develop scientific literacy. The students' group engagements were the only centres of scientific debate and science interrogation.



The feedback that was given by students in the second questionnaire showed that students benefited a great deal from the cooperative orientated lesson in which they were taught NoS. That was shown by the students' eagerness to cooperate in the cooperative groups. Their personal development could be witnessed during the discussions and elaborations they made when presenting their work. Therefore, educational administrators and practitioners should start rethinking the teaching of NoS using cooperative learning.

The implication of this to teacher training is that novice teachers are presently unable to connect their content knowledge to the students' views about science. This research has indicated clearly that teachers must be engaged in serious reflection on how to use that knowledge which guides the transformation of content, in planning for instruction. That reflection needs to be initiated by the Department of Education through subject advisors setting up continuous teacher advancement programmes,



science expos, and vigilant guidance of teachers in this most important field of education for the future of South Africa and its peoples.

Further, it is highly desirable that private business, which relies on well- educated, scientifically literate future employees, should continue to be involved in these advancement programmes which would lead to mutual gains.



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## APPENDIX A: QUESTIONNAIRE

### *Pedagogical Learning for Scientific Literacy Questionnaire (PLSLQ)*

The questionnaire was designed for the purposes of research aiming at uncovering the extent to which physical science teachers engage their students during lesson presentation and also to determine whether or not teachers need to be developed in the use of the cooperative learning approach when teaching nature of science to the secondary school students. The information obtained from this instrument will be used to inform the researcher on preparation of mentoring programme material and generalize on the future needs for professional development of teachers. The names of the respondents will be kept anonymous from this day until the end of the research and also during the reporting stage.

The questionnaire has three categories i.e. teaching of nature of science, cooperative learning use and demographic category. **Please complete all items.**

#### SECTION A: BIOGRAPHICAL VARIABLES

Answer each question by **circling** the appropriate number in the box.

1) Age

23 – 30	1
31 – 36	2
37 – 42	3
43 – 50	4

2) Overall teaching experience.

0 – 2	1
3 – 5	2
6 – 8	3
>9	4

3) Physical science teaching experience.

0 – 2	1
3 – 5	2
6 – 8	3
>9	4

4) Number of years trained to teach Physical science

0 – 2	1
3 – 5	2
6 – 8	3
>9	4

5) What is your highest qualification in teaching?

Teacher's certificate (Certificate in Education)	1
Teaching Diploma (Diploma in Education)	2
Bachelor of Education Degree	3
Advanced Certificate in Education	4
Post Graduate Certificate in Education	5
Honours Bachelor of Education Degree	6
Master's in Education	7

6) What was your major (main) subject(s) during your teacher training course?

Science only	1
Mathematics only	2
Both Science and Mathematics	3
Other (Specify)	4

7) Indicate your post level in your position as a science educator

Post level 1 science educator 1	1
Post level 2 science educator	2
Post level 3/ 4 science educator 1	3
Other (Specify)	4

8) Which grades (classes) are you currently teaching?

Grade 8	1
Grade 9	2
Grade 10	3
Grade 11	4
Grade 12	5
Other (Specify)	6

9) Are you pleased by the general performance of your students in physical science?

Not at all	1
Sometimes	2
Often	3
Generally	4
Almost always	5

10) How frequently do you think there should be professional development particularly in teaching strategies?

Not at all	1
Sometimes	2
Often	3
Generally	4
Almost always	5

11) Do your students accommodate change in teaching strategies?

Not at all	1
Sometimes	2
Often	3
Generally	4
Almost always	5

## SECTION B: Custody of Student Ideology

The following statements ask for your opinion about the curriculum and its day to day elementary activities. Next to each statement please indicate your perception based on the items for the themes given below. The questionnaire included a small number of scales (5), each containing a relatively small number of items. The scale's mean ranged from 1 to 5, with 1 for the most negative perception that represents almost never, 2 represents seldom, 3 represents sometimes, 4 represents often, and 5 for the most positive perception, which represents very often.

Items	Rating				
1. I permit students to asks questions whenever the need arises in class	1	2	3	4	5
2. Before I respond to lesson questions in class, I first give the chance to students to attempt answering the questions.	1	2	3	4	5

3. A variety of assessment tools are used for the purpose of validating learning.	1	2	3	4	5
4. My students are self-motivated and have high self-efficacy	1	2	3	4	5
5. I give students a variety of theory-laden questions in order to challenge their conceptual sentiments	1	2	3	4	5
6. My lessons promote diagnostic patterns of students' views of NOS.	1	2	3	4	5
7. The science knowledge gained from my science class is linked to the needs of the individual social life of a student.	1	2	3	4	5

### SECTION C: Student Perspective of NOS

Items	Rating				
1. My students view science as a practical subject capable of empirical testing.	1	2	3	4	5
2. My students have an understanding that scientific knowledge is developed through understanding nature which contributes to a network of laws, theories and concepts.	1	2	3	4	5
3. Students' enthusiasm towards science investigations is aggravated when they are given an opportunity to exercise their creativity in order for them to arrive at the plausible hypotheses.	1	2	3	4	5
4. Whenever the students are expected to work in an individual project, they perform better than when working in groups.	1	2	3	4	5
5. The socio-cultural context of the majority of my students emphasizes and encourages the learning of certain scientific related skills while minimizing others.	1	2	3	4	5
6. Students hold a perception that science is procedural more than creative.	1	2	3	4	5
7. Students believe that existing scientific knowledge remain relevant only when there is non- refute on such.	1	2	3	4	5
8. Students adhere to the notion that scientists are particularly objective	1	2	3	4	5
9. Students seldom explain scientific phenomena by their indigenous knowledge during in class discussions.	1	2	3	4	5
10. Students are able to design their own problem solving plan which leads to uncovering the scientific truths or supporting existing findings.	1	2	3	4	5

### SECTION D: Nature of Science as a Choice (NOSAC)

Items	Rating				
	1	2	3	4	5
1. I believe that science is developed through observation and empirical evidence is required for justification.					
2. Observations are theory-laden					
3. I am able to raise awareness to my students about the tentativeness of science without them doubting its authenticity and encourage them to identify own field of concern for future scientific research.					
4. Laws and theories serve different roles in science and hence theories do not become laws even with additional evidence.					
5. My lessons engage creativity and expand student imagination and enable them to use their social and historical culture to influence their thoughts.					
6. Scientists use their creativity for the generation of plausibility of their hypotheses in order to formulate theories.					

### SECTION E: Curriculum Principles and Teacher Support on Teaching Strategies

Items	Rating				
	1	2	3	4	5
1. I find it easy to unpack the aims of the current curriculum.					
2. The aims of the current curriculum encourages the teaching of NoS.					
3. The education department is doing something to assist you in understanding and delivering on the aims of the curriculum					
4. There are tools used by the education department to develop and assess the understanding of the teaching strategies promoting scientific literacy.					
5. There are interactions in forums or clubs with other physical science teachers in the cluster from which we discuss teaching strategies for improving student performance.					

### SECTION F: Humanistic Orientation

Please answer these questions to the best of your understanding.

1. Describe the extent to which you can allow your students to use their local knowledge in a science class.

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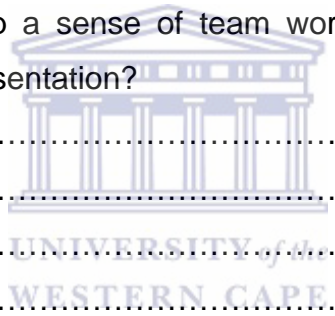


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2. Which endeavours do you employ when a student shows less interest in physical science lessons?

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3. How do you develop a sense of team work amongst students during your physical science lesson presentation?



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4. How do you ensure that safety precautions practiced during your lesson presentations in class do not in any way hinder students' willingness to explore and learn scientific concepts?

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8. How would you encourage your students to learn NoS?

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## APPENDIX B: TRAINING MANUAL

### Welcome to the training session

#### Section A: Curriculum

Students are taught within a certain framework; hence the lessons are designed in such a manner that they achieve the outcomes within that framework. The national curriculum is the culmination of the efforts of the government over a period of time to transform the curriculum bequeathed to the black South Africans by apartheid. From the start of democracy, the government has built the curriculum on the values that inspired the Constitution (Act 108 of 1996). The *National Curriculum Statement Grades R-12 (January 2012)* represents a policy statement (CAPS) for learning and teaching in South African schools from which the general aims are stipulated.

#### Activity 1: Group work

1. List the THREE general aims of the current South African Curriculum and explain how you can use physical science lessons to achieve them.
2. Design a lesson presentation which will achieve at least two aspects of the general aims of the curriculum.
3. What challenges do you face when teaching physical science that may result to learning hindrance in your teaching?

#### Section B

#### Activity 1

Work in groups of THREE and answer the questions below.

(i)	What do you understand about nature of science?
(ii)	Identify one scientific theorist whose work informs the current science curriculum and discuss what you understand about the work of the scientist you chose and how you can use it to influence the students' understanding of their curriculum context.
(iii)	Which activities do you perform in your class that enhance your teaching and ensures the elimination of misconceptions?
(iv)	Have there been any scientific innovations on the work of the scientist of your choice?

(v)	What do you understand about the general aims of the current curriculum and how do you think the understanding of scientific methods can play a crucial role in the achievement of these aims?
(vi)	Discuss whether or not physical science subject matter learning relies on in-depth understanding of scientific theories and laws, interrelating concepts, principles, and themes.

### *Activity 2*

*Work individually when answering this question.*

Read from A to I, and then choose one of the statements and in your opinion state and elaborate with examples on your position regarding the statement which says “scientists are always very open-minded, logical, unbiased and objective in their work. These personal characteristics are needed for doing the best science”.

- (A) The best scientists display these characteristics otherwise science will suffer.
- (B) The best scientists display these characteristics because the more of these characteristics you have, the better you’ll do at science.
- (C) These characteristics are not enough. The best scientists also need other personal traits such as imagination, intelligence and honesty. The best scientists do NOT necessarily display these personal characteristics:
- (D) Because the best scientists sometimes become so deeply involved, interested or trained in their field, that they can be closed-minded, biased, subjective and not always logical in their work.
- (E) Because it depends on the individual scientist. Some are always open-minded, objective, etc. in their work; while others can become closed-minded, subjective, etc. in their work.
- (F) The best scientists do NOT display these personal characteristics any more than the average scientist. These characteristics are NOT necessary for doing good science.
- (G) I don’t understand.
- (H) I don’t know enough about this subject to make a choice.
- (I) None of these choices fits my basic viewpoint

### *4.2.3 Pre-understanding of cooperative learning*

#### *Teacher Background*

### **Collaborative learning of NoS**

1. Recent research studies on science education acknowledge that scientific knowledge relies heavily, but not entirely, on observations, experimental evidence, rational arguments, and scepticism. What is your opinion with regard to this statement? Give a detailed explanation with examples based on a physical science lesson presentation in order to support your opinion.
2. In your experience as a physical science teacher would you argue that observations are theory-laden?
3. Considering the fact that science changes with new developments in research, explain how you would make your students aware of that fact without them doubting the authenticity of science as a way of explaining natural phenomena.
4. You are asked to elaborate on the statement that says Laws and theories serve different roles in science and hence theories do not become laws even with additional evidence; how would you explain that?
5. Research shows that the number of emerging scientists is not growing the way it is expected, looking at the number of challenges the world is facing. In order to remedy this situation, science teachers are urged to motivate students into considering science growth and development. Explain how you would enable students to use their social and historical culture to influence their scientific thoughts.
6. Scientists are creative and often resort to imagination and speculation; explain how you would provide insight into that kind of behaviour to your students.

In order to achieve this goal, two categories were identified.

#### *Category 1: Nature of science exposition*

With the aid of the fact that the important aspects of NoS are in one way or the other viewed controversial, the aspects, which I believe are accessible to secondary school students and relevant to their daily lives, were adopted and emphasized for the purpose of developing the views of nature of science (VNOS). NoS views considered were tentativeness of scientific knowledge; scientific knowledge being empirical; theory-laden; partly the product of human inference, imagination, and creativity; and

socially and culturally embedded. The following questions were given to the participants and they were expected to respond to them individually.

### **Questions**

1. *Recent research studies on science education acknowledge that scientific knowledge relies heavily, but not entirely, on observations, experimental evidence and rational arguments. It is also evident that science changes with new developments in research, and students have to be aware of this fact and still not doubt the authenticity of science as a way of explaining natural phenomena. Design a physical science lesson from which the above can be proved to be true. Give brief explanation with examples based on the current curriculum in order to support this notion.*
2. *Scientists do not have direct access to most natural phenomena. Explain how you think they gather information explanations they have with regard to natural phenomena.*
3. *Laws and theories serve different roles in science and hence theories do not become laws even with additional evidence. How would you explain that?*
4. *In your experience as a physical science teacher would you argue that scientific knowledge is theory-laden?*
5. *Research shows that the number of emerging scientists is not growing the way it is expected, looking at the number of challenges the world is facing. In order to remedy this situation, science teachers are urged to motivate students into taking part in science growth and development. Explain how you would encourage students to use their social and historical culture to influence their scientific thoughts while you advocate for science as a human enterprise.*
6. *Scientists are creative and often resort to imagination and speculation. Explain how you would provide insight into that kind of behaviour to your students.*

#### **3.4.2.1 How to teach NoS explicitly using cooperative learning?**

'Those who understand, translate the information and those who don't, transfer it.'

The teacher asks the students to describe what an atom is. After they have given the answer to their understanding, they are then asked to explain how they came about with the definition they gave. After the discussions on the sources of their knowledge, the teacher will have to reveal to the students that even the knowledge they have may

not be like that in the years to come due to new evidence that could result from new investigations. During this session, the students are taken through the **Development of the Theory**, closely looking at how scientists know what they claim more than what they know. Through this process students are enlightened through scientific developments that what they know today could have been transferred to them but they should view science as a way of knowing.

An atom is the smallest particle into which an element can be divided and still be the same substance and an Element is a pure substance that cannot be separated into simpler substances by physical or chemical means. Atoms make up elements and elements combine to form compounds. Furthermore all matter is made of elements or compounds, so all matter is made of atoms, though no one had ever seen one. However ideas, or theories, about atoms have been around for over 2,000 years.

What is a Theory? This is a unifying explanation for a broad range of hypotheses and observations that have been supported by testing. This therefore means that there were investigations done on this concept and there were observations made that led to this conclusion. Then we speak of how scientists know what they know, i.e. through theory-laden. Scientific knowledge is subjective and/or theory-laden. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work. All these background factors form a mind-set that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they make sense of, or interpret their observations. It is this (sometimes collective) individuality or mind-set that accounts for the role of subjectivity in the production of scientific knowledge and is noteworthy that, contrary to common belief, science rarely starts with neutral observations. Observations and investigations are motivated and guided by, and acquire meaning in reference to, questions or problems surrounding a particular concept. These questions or problems, in turn, are derived from within certain theoretical perspectives. Often, hypothesis or model testing serves as a guide to scientific investigations.

#### *Development of the Atomic Theory*

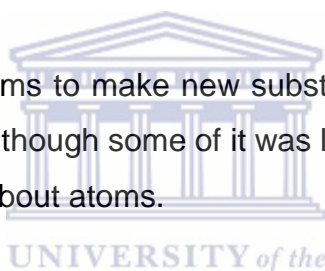
Democritus (440 B.C.)- proposed that if you kept cutting a substance in half forever, eventually you would end up with an indivisible particle which he called atoms,



meaning “indivisible” in Greek. Democritus thought that atoms were small, hard particles of a single material and in different shapes and sizes. He thought that atoms were always moving and formed different materials by combining with each other. Contrary to this, Aristotle disagreed with Democritus’s idea that you would end up with an indivisible particle and, because he had greater public influence, this led to Democritus’s ideas being ignored for centuries.

From the fact that scientists knew that elements combined with each other in specific proportions to form compounds, John Dalton (1803) claimed that the reason for this was because elements are made of atoms. He published his own three-part atomic theory:

- 1) All substances are made of atoms and atoms are small particles that cannot be created, divided, or destroyed.
- 2) Atoms of the same element are exactly alike, and atoms of different elements are different.
- 3) Atoms join with other atoms to make new substances. For a long time much of Dalton’s theory was correct, though some of it was later proven incorrect and revised as scientists learned more about atoms.



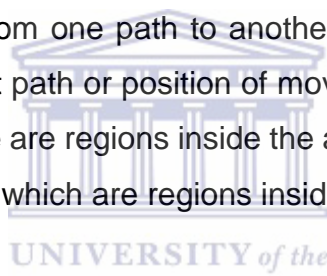
J.J. Thomson (1897) used a cathode-ray tube to conduct an experiment which showed that there are small particles inside atoms. This discovery identified an error in Dalton’s atomic theory and proved that atoms can be divided into smaller parts. Because the beam moved away from the negatively charged plate and toward the positively charged plate, then Thomson knew that the particles must have a negative charge. He called these particles corpuscles which we now call electrons.

After Electrons were discovered to be the negatively charged particles found in all atoms, Thomson changed the atomic theory to include the presence of electrons. He hypothesised that there must be positive charges present to balance the negative charges of the electrons, but he didn’t know where. Thomson proposed a model of an atom called the “plum-pudding” model, in which negative electrons are scattered throughout soft blobs of positively charged material.

Whilst satisfied with Thompson’s model, Ernest Rutherford (1909) conducted an experiment in which he shot a beam of positively charged particles into a sheet of

gold foil and had predicted that if atoms were soft, as the plum-pudding model suggested, the particles would pass through the gold and continue in a straight line. Most of the particles did continue in a straight line. However some of the particles were deflected to the sides a bit, and a few bounced straight back. Rutherford realized that the plum pudding model did not explain his observations and decided to change the atomic theory and so developed a new model of the atom. Rutherford's model says that most of the atom's mass is found in a region in the centre called the nucleus and the nucleus being the tiny, extremely dense, positively charged region in the centre of an atom. Rutherford had calculated that the nucleus was 100,000 times smaller than the diameter of the atom. In his model the atom is mostly empty space, and the electrons travel in random paths around the nucleus.

In 1913, Niels Bohr suggested that electrons travel around the nucleus in definite paths located at certain levels from the nucleus. Electrons cannot travel between paths, but they can jump from one path to another which is the current or modern model that exists. The exact path or position of moving electron cannot be predicted or determined. Rather, there are regions inside the atom where electrons are likely to be found in electron clouds, which are regions inside an atom.



This therefore drives us to conclude that scientific knowledge is never absolute or certain. This knowledge, including “facts,” theories, and laws, is tentative and subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programmes. Adding to this discussion scientific knowledge is, at least partially, based on and/or derived from observations of the natural world (i.e., empirical), it nevertheless involves human imagination and creativity. Contrary to common belief, science is not a totally lifeless, rational, and orderly activity, but rather involves the invention of explanations, and this requires a great deal of creativity by scientists. This aspect of science, coupled with its inferential nature, entails that scientific concepts, such as atoms, black holes, and species, are functional theoretical models rather than faithful copies of reality.

The atomic theory model discussed in this study and its development, observation and inference, remained distinct from scientific laws and therefore students have to

understand that theories and laws are different kinds of knowledge, and one does not develop or become transformed into the other. Scientific models are common examples of theory and inference in science and moreover, theories are as legitimate a product of science as laws. Scientists do not usually formulate theories in the hope that one day they will acquire the status of law (Lederman, 2007).

#### *Category 2: Cooperative learning tools and Pedagogical Content Knowledge scheme*

In this category, teachers were given notes and activities that can be given to students in class, on the main principles that were taken into consideration.

#### *3.4.2.2. Cooperative learning as pedagogy and the structure of a CL incorporated lesson presentation.*

There are three main types of cooperative learning groups: informal learning groups, formal cooperative groups and cooperative base groups. We'll define each and discuss the best situation to use each type of group.

##### *Informal Learning Groups*

These groups are short term and not very structured. They typically involve activities where classmates turn to a neighbour to discuss a problem or concept, ranging from few minutes to a class period. Informal groups are generally small, usually ranging between two to four people (Johnson, Johnson, & Holubec, 1998). It is most convenient to use informal learning groups for quick activities such as checking for understanding, brainstorming, quick problem solving, summarising, or review. These groups are a great way to vary a lecture format by giving students a few minutes to discuss a concept with a peer in order to achieve a joint learning goal.

##### *Formal Learning Groups*

Formal learning groups are assigned a task or project and stay together until it is complete. There is a clear structure to these groups, set by the teacher, which includes task and behaviour expectations. Formal learning groups can be heterogeneous or homogeneous, depending on the assignment. Most groups perform well with three to five people and any more than five could become unproductive. According to Smith, Sheppard, Johnson & Johnson (2005) formal learning groups can

be effective in the classroom when students are engaged in activities are project based, solving a series of problems, reviewing for a test, or writing a report. They further emphasised that these activities are very beneficial in content intensive classes where the focus is on mastery of conceptual or procedural materials.

### *Cooperative Base Groups*

These groups are different from the previous two in that they are long term support groups. Base groups should last for a minimum of a semester but can be anywhere up to several years. Since they are long term commitments, typically these groups become more than just academic problem solving groups. Members in base groups often become a personal support system for each other, building relationships and trust during the duration of their cooperative learning process. The goal of cooperative base groups is that the members develop peer accountability and support each other while learning together.

It is acceptable to use more than one type of group at a time! For example, you can assign a project using formal learning groups and still use informal groups during teaching time where the formal groups are not working together. If you have a class where cooperation is a challenge, you may need many opportunities for your students to practise working together. Begin simply and work your way towards more formal cooperative learning situations.

During the mentoring programme, informal and formal cooperative groups were practised more often in order for teachers to acquaint themselves with the teaching strategy.

### *Possible classroom activities*

In order to engage students' cognitive thinking, teachers were advised to use informal cooperative groups and give students a glass rod with a silk cloth; ask them what happens when you rub against the two objects as shown in Figure 4.

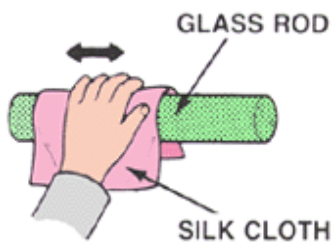


Figure 4: Silk cloth rubbing the glass rod

Identify roles for the group members so everyone has a particular task to do and specific way to contribute, depending on the task at hand, e.g. student A will facilitate thought sharing, student B take notes of the different ideas, student C presents the group's conclusive idea and student D leads in answering of questions from the classmates and additions on the idea. Students should also be given time to think individually about the question and enable them to write their thoughts down before they can share them, and time to share their thoughts with their group members. By doing so you allow yourself to get things off to a good start by structuring and enforcing collaborative learning, and build their confidence as they could be grouped with people they do not know. While groups are working during class, circulate in the room to make sure everyone is connected with a group, follow up afterwards with feedback about what went well with the groups and what could be improved next time, and reiterate the importance of everyone contributing. Students will be more committed to group work and more comfortable with it if they see your commitment to making sure groups work well for their learning.

After they have finished giving their group reports, explain to the students by first explaining the origin of atoms, and its scientific developments, e.g. J. Dalton's atomic theory which describes all matter in terms of atoms and their properties, J.J. Thomson's experiments with cathode ray tubes showing that all atoms contain tiny negatively charged subatomic particles or electrons, Thomson's plum pudding model of the atom having negatively-charged electrons embedded within a positively-charged "soup", and Rutherford's gold foil experiment showing that the atom is mostly empty space with a tiny, dense, positively-charged nucleus. Indicate to students how the atomic models differ from each other according to the scientist's claims e.g. an atomic model according to Figure 5.

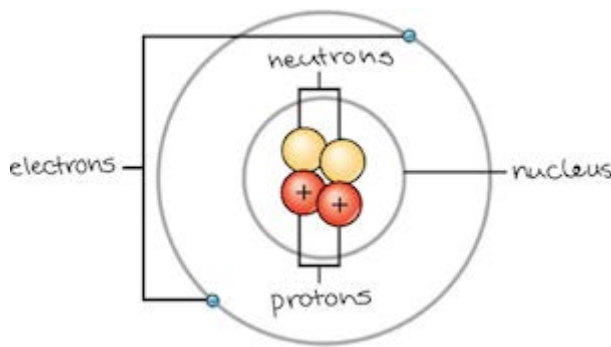


Figure 5: Atomic Model

As you highlight the development of science around the atom structure your students should take notes and later discuss them with their peers in a group. Whilst doing so, reiterate on static electricity, electric charge and its conservation.

Static electricity is referred to as electricity at rest. It is an electrical charge that builds up due to friction between two dissimilar materials. Due to electrons being loosely bound, in conducting objects, they are so loosely bound that they may be induced into moving from one portion of the object to another portion of the object. Friction removes electrons from one object and deposits them on the other and each object is said to be charged. The one acquiring electrons is said to be negatively charged, while the one that lost electrons is said to be positively charged.

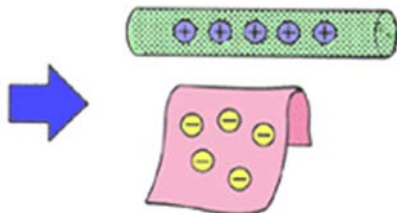


Figure 6: Charged objects from rubbing

Let students experiment that the two objects have gained different charges by allowing the objects closer to uncharged objects. Allow students to brainstorm on what could be the reason for the objects to behave in the manner in which they do. Later explain to your students the concept of polarisation, like charges cause repulsive behaviour and unlike or opposite charges attractive behaviour.

#### *Polarisation and repulsive, attractive behaviour of charges*

##### Part (a)

To get an electron in a conducting object to *get up and go*, all that must be done is to place a charged object near the conducting object. If the negatively charged object

(e.g. balloon) is brought near any conducting object (e.g. aluminium pop can), the electrons within the pop can will experience a repulsive force. The repulsion will be greatest for those electrons that are nearest the negatively charged balloon. Many of these electrons will be induced into moving away from the repulsive balloon. Being present within a conducting material, the electrons are free to move from atom to atom within an object. As such, there is a mass migration of electrons from the balloon's side of the aluminium can towards the opposite side of the can. This electron movement leaves atoms on the balloon's side of the can with a shortage of electrons; they become positively charged, and the atoms on the side opposite of the can have an excess of electrons; they become negatively charged. The two sides of the aluminium pop can have opposite charges. Overall the can is electrically neutral; it's just that the positive and negative charge have been separated from each other. We say that the charge in the can has been polarized.

### Inducing Electron Movement Within a Conductor



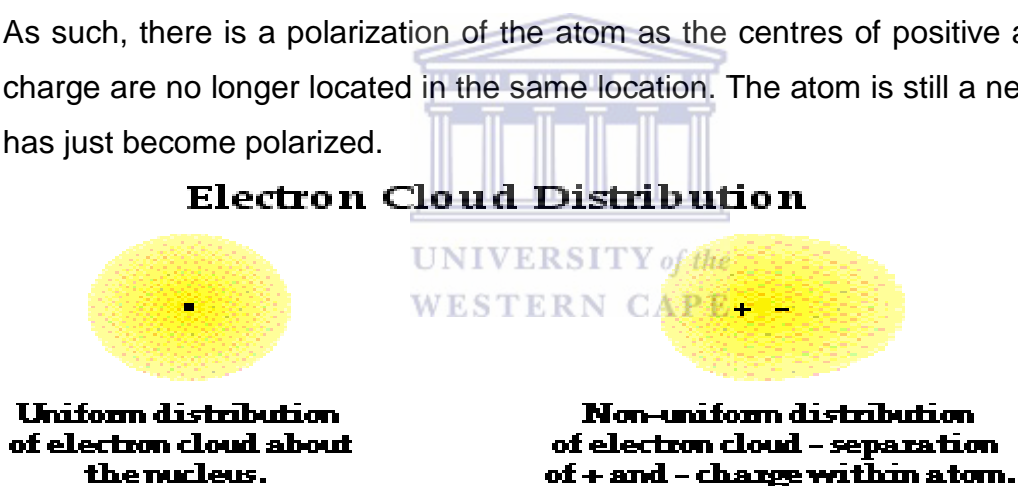
Figure 7: Polarisation in a conductor

Therefore, explain to students that, with respect to electric charges, polarization process involves the use of a charged object to induce electron movement or electron rearrangement, which can be identified with both repulsive and attractive behaviour of charges, where a negative charge by the cloth repels the negative charge of the can and positive charge of a can is attracted to the negative charge of the cloth.

#### Part (b)

With the insulator, the process occurs in a different manner than it does within a conductor. In an insulator, electrons merely redistribute themselves within the atom or molecules nearest the outer surface of the object. To understand the electron redistribution process, it is important to take another brief excursion into the world of atoms, molecules and chemical bonds.

The electrons surrounding the nucleus of an atom are believed to be located in regions of space with specific shapes and sizes. The actual size and shape of these regions is determined by the high-powered mathematical equations common to Quantum Mechanics. Rather than being located a specific distance from the nucleus in a fixed orbit, the electrons are simply thought of as being located in regions often referred to as electron clouds. At any given moment, the electron is likely to be found at some location within the cloud. The electron clouds have varying density; the density of the cloud is considered to be greatest in the portion of the cloud where the electron has the greatest probability of being found at any given moment. And conversely, the electron cloud density is least in the regions where the electron is least likely to be found. In addition to having varying density, these electron clouds are also highly distortable. The presence of neighbouring atoms with high electron affinity can distort the electron clouds around atoms. Rather than being located symmetrically about the positive nucleus, the cloud becomes asymmetrically shaped. As such, there is a polarization of the atom as the centres of positive and negative charge are no longer located in the same location. The atom is still a neutral atom; it has just become polarized.



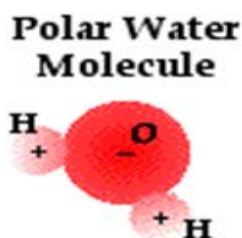
*Figure 8: Uniform and Non-uniform electron cloud distribution.*

Part (c)

Take your students further and ask them to determine whether or not charges were moved or transferred from one object to another during the polarization of the can. Let the discussion become even more complex by considering the formation of molecules whereby atoms are bonded together. Allow students to do research on this topic and give time in class for them to argue their cases as groups. The form of grouping that shall have been used during this project would be formal cooperative grouping. Try by all means to elicit their understanding; reiterate the acceptable conceptions.



Explain and expand your students' knowledge by making use of models analogy, like the example of a tug-of-war between a wrestler and a toddler and the use of the plastic ball atomic model. In molecules, atoms are bonded together as protons of one atom attract the electrons in the clouds of another atom.



*Figure 9: Polar Water Molecule model*

This electrostatic attraction results in a bond between the two atoms. Electrons are shared by the two atoms as they begin to overlap their electron clouds. If the atoms are of different types (for instance, one atom is Hydrogen and the other atom is Oxygen), then the electrons within the clouds of the two atoms are not equally shared by the atoms. The clouds become distorted, with the electrons having the greatest probability of being found closest to the more electron-attracting atom. The bond is said to be a polar bond. The distribution of electrons within the cloud is shifted more towards one atom than towards the other atom. This is associated with the ability of an atom to attract the electron shared pair of electrons to itself, which is called electronegativity. This is the case for the two hydrogen-oxygen bonds in the water molecule share its electrons and these two atoms are drawn more towards the oxygen atom than towards the hydrogen atom. Subsequently, there is a separation of charge, with oxygen having a *partially* negative charge and hydrogen having a *partially* positive charge. A dipole is formed and the bond is said to be polar which implies that greater electronegativity difference results in greater polarity.

*(This section was adapted from The Physics Classroom Tutorials written by Tom Henderson since 1996)*

### 3.4.2.3 The elements of the CL method.

During the lesson presentation, teachers are expected to monitor whether or not students practise the main elements of cooperative learning. In this lesson students

were allowed to explore and use their social skills and the teachers working together to achieve the desired goals. These were the aspects that teachers were looking out for:

- *Positive interdependence* whereby students were encouraged to work towards achieving a common goal creating a friendly and accommodating group atmosphere where every group member had an equal opportunity to express himself or herself and was listened to with respect. Students were brought together by means of clear identification of roles as a group and particularly an individual role to understand the content dealt with in class.
- *Face-to-face promotive interaction* was crucial as students had to understand the importance of helping one another learn, applauding effort and success. Helping one another was envisaged to yield promotive interaction whereby students exchanged resources, testing hypotheses together and challenging each other's conclusions but at the end, based on scientific epistemology, arrive at the solution. This was done by means of probing questions that required theory testing and students were urged to clarify to group members by means of known models.
- *Individual and group accountability* put emphasis on individual efforts to make contributions in order to understand the task at hand, which will, in return, endorse individual gains in the process. Each member of the group, to a certain extent, has to contribute to the assigned work so that when assessment is done, every individual is able to demonstrate effort and learning in the interaction process. The teacher had to clearly identify roles and also allow students to give feedback on challenges they had experienced as they were working in their small groups.
- *Interpersonal and small group skills* could defeat the purpose if not gradually fostered and developed as groups depend on them. Communication, trust, leadership, decision making, and conflict resolution skills had to be nurtured by encouraging students to commit to their work so that they could express themselves clearly and with confidence. Each group member was encouraged to view knowing everyone in the group as an obligation, appreciate their individual differences, embrace one another's strengths and, above all, develop their weaknesses into strengths. This would enhance communication and limit conflicts.
- *Group processing* had to be assessed as it would reflect on how well the team was functioning and how it could function even better by giving brief feedback for further improvement and facilitation of cooperative learning skills.

#### 3.4.2.4 *Benefits of sharing content knowledge and conceptual understanding amongst teachers*

The historical background of cooperative learning has shown it to be an unusually strong psychological success story. From being discounted and ignored in the 1940s through the 1970s, cooperative learning is now a standard and widespread teaching procedure that has been adopted by many countries when developing their curriculum, hoping for skill development and preparing them for the work place. According to Gillies & Ashman (2003) the approach has been recognized for its importance, in contrast to the traditional classroom, as an effective approach to teaching.

Through cooperative workshop activities, teachers were exposed to the practice of content sharing, without shame or fear of being judged, for the purpose of personal development and that of a group. During this exercise they were able to negotiate meaning about their work, thus developing shared goals of fostering students' higher level of thinking skills and creativity- adopting specific instructional strategies for specific purposes. The programme then adopted and introduced the peer coaching and co-teaching resonate in the teaching and learning setting as suggested by Goodnough, K., Osmond, P., Dibbon, D., Glassman, M. & Stevens, K. (2009). Teachers often complained that professional development learning experiences were not in line with everyday teaching situations; as a result, the learning experiences do not have meaningful effects on their teaching practice. In cases like this, peer coaching and co-teaching became meaningful as the teachers understood the actual science teaching practices.

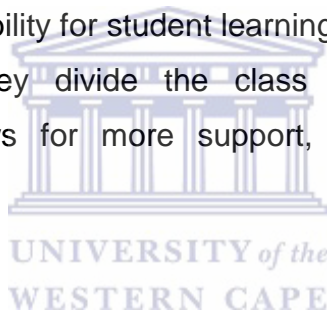
The mentoring programme avoided the traditional mentoring relationship where the authority imparts knowledge to the novice; instead, it took a partnership form where both team members could learn with and from one another. The intention was that of shifting one member's conceptual knowledge about teaching, which was something that could not be attained in the short time period available during a workshop presentation. Participants were advised to draw from Matlin & Carr (2014) as they recommended in their study that the co-teacher should be chosen thoughtfully; they also raised the importance of making sure that you and your team teacher complement one another in multiple areas, where members would want to create a

partnership in which each person can play off one another's strengths, from a disciplinary, personality, or teaching style perspective. Geographic considerations could be an issue of concern but still, co-teachers had to put careful thought into choosing a mentor.

The programme guided the teachers in how to implement co-teaching during a lesson, taking its key aspects into consideration.

### *Co-teaching*

Co-teaching is the instructional arrangement in which a general education teacher and a special education teacher deliver core instruction along with specialized instruction, as needed, to a diverse group of students in a single physical space. Co-teaching partnerships require teachers to make joint instructional decisions and share responsibility and accountability for student learning. Teachers are both teaching the same information, but they divide the class into equal groups and teach simultaneously. This allows for more support, more supervision and greater participation from students.



### *Implementation*

Students are divided into equal-sized groups similar to cooperative learning groups whereby each teacher teaches the same content in the same amount of time.

Instructional methods may differ and groups do not rotate.

### *Opportunities*

Students have an increased opportunity for response and participation due to lower student-to-teacher ratio. In this model both teachers play an active role in instructing the students.

### *Challenges*

Schools and teachers may face challenges with this model as they need to identify appropriate physical space and must have adequate knowledge of content and

pedagogical skills to provide equally effective instruction. However, having two teachers instructing at the same time may be distracting, especially when the students are not used to this kind of instruction, but if well planned, students cope with it quite well.

#### 3.4.2.5 *Instructional Practices and Teacher Perceptions*

Before the end of the mentoring programme, the researcher aspired to obtain the perceptions of the participants with regard to the instructional strands which the programme followed. On the last day of the workshop, the participants were requested to evaluate the workshop with the aid of an evaluation form. The evaluation form was designed in a manner that would enable the researcher to easily analyze data according to themes. Data were collected using this instrument and analysed later.



## APPENDIX C: EVALUATION FORM

Name:				
After the workshop, how do you rate your	Low	Medium	High	
1. Level of satisfaction with the workshop	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
2. Understanding of what cooperative learning is	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
3. Eagerness with regard to the use of cooperative learning	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
4. Skill to work with cooperative learning groups	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
5. Ability to assign roles in cooperative groups for functionality	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
6. Ability to facilitate learning in cooperative learning groups	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
7. Skills to encourage students to interact in a classroom using their social frameworks	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
8. Views of teaching nature of science to secondary school science students	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
9. Knowledge with regard to using NOS as an instructional method	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
10. Ability to use nature of science to diagnose student's areas of difficulty	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
11. Ability to teach students not only what scientists know but also how they know it.	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
12. Eagerness to share scientific developments and teaching strategies	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
13. Content knowledge development on the topics dealt with during the workshop	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
14. Attitude towards teaching science for scientific literacy	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
15. Views in terms of improved performance when teaching NOS to secondary school students	<input type="radio"/> 1	<input type="radio"/> 2 <input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5

## APPENDIX D: GRADE 11 LESSON PLAN

### TOPIC: ELECTRIC FIELD AT A POINT

#### LESSON OBJECTIVES

- Define the magnitude of the electric field at a point as the force per unit charge
- Deduce that the force acting on a charge in an electric field is  $F = Qe$
- Calculate the electric field at a point due to a number of point charges, using the equation  $E = k \frac{Q}{r^2}$  to determine the contribution to the field due to each charge.

#### 2. LESSON DEVELOPMENT

##### 2.1 Introduction

a) PRE-KNOWLEDGE students need understanding of the following:

- (i) Coulomb's Law
- (ii) Electrostatic force
- (iii) Magnetic Field

##### 2.2 Main Body

- (a) Demonstrate the relations between electric field, magnetic field and gravitational field.
- (b) Introduce potentials, a concept essential to electromagnetics as electric field at a point.
- (c) Work with calculations related to the electric field at a point.

##### 2.3 Conclusion

Recall that fields exist even if there are *no* test charges around to probe them. That means that we don't need to use *actual* charges to measure a field—we could simply imagine a “what if?” scenario, and determine the field by *pretending* that a test charge (of arbitrary and unknown charge “*q*”) were present, and computing the force per unit of imaginary charge. Since we are dividing out the value of *q*, it won't even matter that *q* itself *doesn't actually exist!*

##### Student activities

- 1 Calculate the magnitude and direction of the electric field at a point P which is point charge  $Q = -3.0 \mu\text{C}$ .
- 2 Two point charges are separated by a distance of 10.0 cm. One has a charge of  $-25 \mu\text{C}$  and the other  $+50 \mu\text{C}$ .

(a) What is the direction and magnitude of the electric field at point P in between them that is 2.0 cm from the negative charge?

### **PART OF THE NOTES GIVEN TO STUDENTS**

**I. Force & Coulomb's Law:** Coulomb's Law is an empirical rule describing the force between charged particles. (By "empirical", we mean that the law is a principle inferred from *experimental* observation and measurement.) The two most important preliminary issues we must realize are: **(1) Coulomb's Law only applies between pairs of charged particles;** and **(2) Coulomb's Law is only accurate if the charges involved are *point like*.** **(3) The forces implied by Coulomb's Law are always along the direct line joining the two charges.** If they are *like* charges, the force is repulsive, while if they are *unlike* charges, the force is attractive.....

Technically, every charge is simultaneously a source charge and a test charge, since every charge creates its own electric field, and every charge experiences forces due to the fields created by *other* charges. However, **no charge ever creates a field that exerts a force back on that same charge.** (Equivalently, "No charge ever exerts an electrostatic force on itself."—can you see *why* this must be true?) In practice, for any particular charge, it's an "either/or" distinction—*either* we are interested in the field which that charge creates, *or else* we are concerned with how that charge responds to a field that already exists.



## APPENDIX E: GRADE 10 LESSON PLAN

**TOPIC:** Gravitational Potential and Mechanical Energy

### LESSON OBJECTIVES

- Define gravitational potential energy
- Determine gravitational potential energy of an object
- Determine the mechanical energy

### 2. LESSON DEVELOPMENT

#### 2.1 Introduction

a) PRE-KNOWLEDGE students need understanding of the following:

- (i) Different forms of energy
- (ii) Potential energy of an object

#### 2.2 Main Body

(a) Gravitational potential energy is the energy an object has due to its position in a gravitational field relative to some reference point. Gravitational potential energy ( $E_p$ ) is a scalar quantity and is measured in Joules (J). \* Some books use the symbol PE or U for gravitational potential energy

where

$E_p$  = gravitational potential energy (measured in joules, J),

$m$  = mass of the object (measured in kg)  $g$  = gravitational acceleration ( $9,8 \text{ m}\cdot\text{s}^{-2}$ )

$h$  = perpendicular height from the reference point (measured in m)

*Reference point is the zero energy level. Example of this reference point is the ground.*

Gravitational potential energy ( $E_p$ ) of an object is directly proportional to the mass of an object.  $E_p \propto m$ ; and

Gravitational potential energy ( $E_p$ ) of an object is directly proportional to the height of an object  $E_p \propto h$

#### Example

A brick with a mass of 2kg is lifted to the top of a 5 m high roof. It slips off the roof and falls to the ground. Calculate the gravitational potential energy of the brick

a) at the top of the roof

b) on the ground once it has fallen.

(b) Mechanical energy (EM) is the sum of the gravitational potential energy and the kinetic energy of a system. Mechanical energy is mathematically written as:

$$E_{mech} = E_p + E_k \text{ which can be expanded to } E_{mech} = mgh + \frac{1}{2}mv^2$$

The symbols E and I are sometimes used to denote mechanical energy, but for this lesson  $E_{mech}$  will be used. Mechanical energy is measured in Joules (J), the same unit as gravitational potential energy and kinetic energy. NB. It is scientifically wrong to mix symbols in an equation e.g.  $E_{mech} = PE + K$ . Though each symbol represents the correct energy, the symbols were used inappropriately.

### Example 2

Calculate the total mechanical energy for a ball of mass 0,15 kg which has a kinetic energy of 20 J and is 2 m above the ground.

### 2.3 Conclusion

Student activities

- 1) Climbing a vertical rope is difficult. You have to lift your full body weight with your arms. If your mass is 60 kg and you climb 2.0 m, by how much do you increase your gravitational potential energy?
- 2) A block of bricks is raised vertically to a bricklayer at the top of a wall using a pulley system. If the block of bricks has a mass of 24 kg, what is its weight when it is raised 3,0 m? Calculate its increase in gravitational potential energy when it reaches the top of the wall.
- 3) Frank, a San Francisco hot dog vendor, has fallen asleep on the job. When an earthquake strikes, his 3,00 X 10<sup>2</sup> kg hot dog cart rolls down Nob Hill and reaches point A, 3 m above the ground at a speed of 8,00 m·s<sup>-1</sup>. Calculate the mechanical energy of the cart at A.
- 4) A stone with a mass of 50 g is thrown vertically upwards into the air. At a height of 8 m above the position it was thrown, the stone has a velocity of 6 m·s<sup>-1</sup>. Determine the mechanical energy of the stone at a height of 8 m

## APPENDIX F: PRACTICUM REVIEW QUESTIONNAIRE

The questionnaire included a small number of scales (5), each containing a relatively small number of items. A Likert scale was used to obtain the responses to the items. The Likert scale ranged from 1 to 5, with 1 for the most negative perception that represents not at all, 2 represents sometimes, 3 represents often, 4 represents generally, and 5 for the most positive perception, which represents almost always.

Items	Rating				
	1	2	3	4	5
1. I was more patient while being part of a small group.	1	2	3	4	5
2. Working in a group helped me to overcome my shyness.	1	2	3	4	5
3. I enjoyed helping my group members with what I am good at.					
4. My group was more organized than the rest of the groups in my class.	1	2	3	4	5
5. Everyone in the group wanted to contribute towards the assigned tasks.	1	2	3	4	5
6. Members in my group benefited from my contributions to learn the material.	1	2	3	4	5
7. The learning material is easier to understand when working with other students	1	2	3	4	5
8. I view nature of science as the way of knowing	1	2	3	4	5
9. The knowledge on the development of science with regard to the lesson was irrelevant in this lesson	1	2	3	4	5
10. Teachers were able to identify my areas of difficulty	1	2	3	4	5
11. I understand how scientists arrived at the scientific conclusions for this particular concept.	1	2	3	4	5
12. The lesson has taught me that science changes with new observations and evidence.	1	2	3	4	5
13. I understand the concept better now.	1	2	3	4	5
14. I have learnt that there is no one way method of arriving at scientific conclusions	1	2	3	4	5
15. The lesson has made me realize that scientific laws and theories are derived from human curiosity.	1	2	3	4	5
16. The lesson presented encouraged further individual physical science related research.	1	2	3	4	5
17. I learnt that science can be learnt from social contexts.	1	2	3	4	5